ESSAYS ON IMMIGRATION

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This dissertation analyzes different dimensions of the impacts of immigration from a host country perspective. The focus of the first chapter is on the link between wage premium paid to college education and immigration in Canada. College education premium remained stagnant between 1981 and 2008 in the country. Meanwhile the proportion of hours worked by college graduates among immigrants increased significantly. I use a partial equilibrium model to explore the impact of increasing share of college-graduate immigrants on the sluggish movement of skill premium. I run two counterfactual experiments to achieve this objective. The results from both experiments shows that the increase in the share of skilled immigrants had a negative impact on the college premium in Canada. The second chapter is a joint study with David Brown, Julie Hotchkiss, Myriam Quispe-Agnoli. In this chapter we investigate how the employment of undocumented workers varies along the U.S. business cycles in comparison to the employment of documented workers. We illustrate that undocumented employment is significantly more volatile than the documented employment. The explanation we propose for this evidence is the higher elasticity of substitution between undocumented labor and capital compared to documented labor. Using a partial equilibrium model we can explain 80% of the volatility of the cyclical component of undocumented employment during the 2000s. The last chapter analyzes the impacts of immigration on the earning, welfare, and college attainment of native Canadians. It is an extension of the partial equilibrium model in chapter 1 to a general equilibrium setting. The findings in this paper suggest that the shift in the composition of immigrants towards college graduates discourages some natives from college education. The welfare impacts of immigration on natives

are also analyzed. An interesting result in this analysis is that the shift in the composition of immigrants towards college graduates increases the welfare of college-graduate natives as well as the ones with less than college education. The reasons for this surplus accruing to natives are an increase in the wage earnings of both education groups as well as the decrease in the tax rates on labor income.

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PREFACE

I owe my deepest gratitude to my advisors, Daniele Coen-Pirani and Marla Ripoll. They enlightened my way during my graduate study with their excellent guidance, caring and patience. Not only they provided me with great inspiration related to my research but also I learned how to be a great professor from them. I am grateful to my dissertation committee members David N. DeJong and James Feigenbaum for their insightful comments and the help they provided. It was a great opportunity to work with them. I also thank my dear friends Umut Ozbek, Tuna Toptan, Isa Emin Hafalir and Elif Incekara Hafalir who made the difficult days easy, and sad days happy. Lastly I dedicate this dissertation to my father Tahsin Genc, mother Gulperi Genc, brother Bilal Genc, and sister Burcin Genc who were always with me despite the ocean between us.

1.0 INTRODUCTION

This dissertation analyzes different dimensions of the impacts of immigration from the host country perspective. In the first chapter I study Canada, which is a country with a distinct immigration policy. Canada started implementing a selective immigration policy targeting individuals with skills such as education, language, etc. A natural outcome of this policy is a change in the education profile of immigrants to include more college-educated individuals. I document that the wage premium paid to college education has remained stagnant between 1981 and 2008 in the country. Using a partial equilibrium model I explore how the increasing portion of college graduates among the immigrant labor force affected the sluggish movement of skill premium. I run two counterfactual experiments to achieve this objective. The results of the first counterfactual experiment suggest that when there is no change in the share of hours worked by college graduates among immigrants, the college education premium increases by 9.7% between 1981 and 2008. In the second counterfactual scenario I simulate an economy in which the foreign born skilled hours grows at the same rate as in the U.S. The results from this counterfactual scenario show that the faster growth rate in college graduate employment accounts for 25% of the difference in the growth rates of skill premium between the two countries.

The second chapter is a joint study with David Brown, Julie Hotchkiss, Myriam Quispe-Agnoli. The focus of this chapter is on the business cycle properties of undocumented workers' employment. We use quarterly data between 1990 and 2008 from the state of Georgia and investigate the adjustment in the employment of undocumented workers along the business cycles. In comparison to documented workers, we find the cyclical component of undocumented employment to be significantly more volatile. We propose the higher elasticity of substitutability between these workers and physical capital compared to the

documented labor in production as an explanation of this evidence. Using a partial equilibrium model where firms produce output with documented and undocumented labor as well as capital we can explain 80% of the volatility of the cyclical component of undocumented employment observed between 2000 and 2008.

In the last chapter I analyze the impacts of immigration on the earning, welfare, and college attainment of native Canadians. This chapter is an extension of the first chapter to a general equilibrium setting. To evaluate Canada's unique immigration policy, which explicitly targets highly educated individuals, first I calibrate my model to 1981 data. Then I simulate the 2008 Canadian economy in which the relative size of the immigrant labor force is larger and the proportion of college graduates among immigrants is higher. Following this, I run counterfactual experiments to analyze the increase in the relative share of immigrants and the shift in their composition. My findings suggest that the shift in the composition of immigrants towards college graduates results in a 7% point lower college attainment rate among natives. The impact of the increase in the proportion of college-graduate immigrants on the college premium among natives amounts to a slight increase. This result is an outcome of higher ability natives being selected into college education in response to having more college-graduate immigrants in the country. The welfare impacts of immigration are analyzed for the highest, lowest, and median ability natives. An interesting result in this analysis is that the shift in the composition of immigrants towards college graduates benefits all three types, including the highest ability individual who is a college graduate. The reasons for this surplus accruing to natives are an increase in the wage earnings of both college graduates and those with less than college education as well as the decrease in the tax rates on labor income.

2.0 SKILL PREMIUM AND IMMIGRATION IN CANADA

2.1 INTRODUCTION

Wage inequality between college graduates and less than college-educated individuals remained stagnant between 1981 and 2008 in Canada. On the other hand a similar country, U.S. has been a place where college educated enjoyed increasing benefits during the same period. The sluggish movement of the college education premium in Canada was accompanied by an increasing share of hours worked by college graduates. The rise in the ratio of college graduate hours to those with below college education among immigrants was an important factor contributing to the growth in the share of hours worked by skilled workers in the country.

The objective of this paper is to evaluate the impact of the shift in the composition of immigrant hours towards college graduates on the slow increase of skill premium in the country. To achieve this objective I use a partial equilibrium model where the output is produced using skilled and unskilled labor together with two types capital. Another important feature of the production technology is that capital is complementary to skilled labor. A production function with these features was first used by Krusell, Ohanian, Rios-Rull and Violante (2000) (hereafter KORV (2000))[50] to analyze the skill premium dynamics in the U.S. I follow their methodology with a particular emphasis on the changes observed in the education composition of immigrant labor force in Canada.

Studying how much international immigration accounts for the evolution of the education premium is important because it has significant policy implications for the country. Canadian immigration policy until the early 1960s was based on a national-origin preference system. This system limited the entry of some national origin groups and facilitated the

entry of others. In 1967, Canada introduced a points system which selected immigrants with desirable skills.[1] This change in the immigration policy of Canada, enhanced the inflow of skilled immigrants to the country. In addition a similar candidate immigration policy is being considered in other developed countries. The most recent example of such countries is France. In 2007, a new immigration law which gives the government new powers to encourage high skilled immigration took effect in the country. Among the main objectives of the new policy are recruiting skilled workers, facilitating foreign students' stay and tightening the rules on family reunification.[2] Therefore a quantitative analysis of an increasing share of skilled immigrants on the relative return to education in labor markets is important to shed light on the possible impacts of a selective immigration policy for other developed countries as well.

The paper is related to two strands of the literature. The first one covers the studies which are concerned with the impact of immigrants on the wage earnings of natives. A brief look at this literature shows that there is conflicting evidence. The spatial approach makes use of the variation in the immigrant inflows in local labor markets to estimate the impacts of immigration. Altonji and Card (1991)[2] treat immigrants and natives as two factors of production, whereas Card (1990, 2001)([21],[22]) assume that immigrants and natives of the same skill group are perfect substitutes. These studies find a small impact of immigrants on the wages of natives. On the other hand, research that use a nation-wide approach find significant and negative impacts of immigration on native earnings. For instance, Borjas, Freeman, and Katz (1997)[14] and Borjas (2003)[13] estimate the impact of immigration on natives of different education and experience groups. These studies find a larger and negative impact of immigration on the wage earnings of the natives. Similarly, Aydemir and Borjas (2007)[5] compare the impact of immigration induced labor supply shocks on the relative earnings of natives in different education groups in the U.S., Canada, and Mexico. Their results suggest that the immigration experience of Canada narrowed the wage inequality due to the high proportion of skilled immigrants. For the U.S. they conclude that the wage inequality increased as a result of immigration since the immigrant population consists more

[1]Source: Kelley, N. and Trebilcock, M. (2010) *"The Making of the Mosaic: A History of Canadian Immigration Policy"*

[2]Source: Murphy, K.(2006) *"France's New Law: Control Immigration Flows, Court the Highly Skilled"*

of low-skilled individuals.

The second closely related literature looks at the college education premium in Canada. Murphy, Riddell and Romer (1998)[61] estimate the impact of the relative supply of skilled workers on the skill premium in Canada and the U.S. They use the Katz and Murphy (1992)[51] model to explain why skill premium moved differently in two countries. Their results suggest that changes in supply appear to be the most important factor causing decade to decade and country to country variation in trends in relative wages of college educated labor.

Kryvtsov and Ueberfeldt (2009)[52] is a more recent work which compares the premium paid to higher education in the U.S. and Canadian labor markets for the 1980-2000 period. They use a partial equilibrium model with a production technology a la KORV (2000)[50]. They find the difference in the fraction of university graduates in the working age population in 1980 and the growth rate of this fraction to account for two thirds of the education premium difference between the U.S. and Canada.

This paper is closely related to Aydemir and Borjas (2007)[5] and Kryvtsov and Ueberfeldt (2009)[52]. Different from Aydemir and Borjas (2007)[5], I use a production technology which has the feature of complementarity between capital and skilled labor. Kryvtsov and Ueberfeldt (2009)[52] use the same production technology however they do not consider the impact of the changes in the relative skilled hours among immigrants. The special emphasis of this paper on immigrants and the impact of the shift in their composition on college education premium is a key element distinguishing this paper from Kryvtsov and Ueberfeldt (2009)[52].

The remainder of the paper is as follows. In section 2.2, I discuss some Canadian data facts. The subsequent section is the quantitative analysis part where I explain the model, its parameters and their specification. This section also includes an assessment of the model in matching the behavior of skill premium in the country for the 1981-2008 period as well as the results of the counterfactual experiments. The last section summarizes the results and concludes.

2.2 DATA

In this section I present some stylized facts about the relative wages and the total hours worked by college-educated and non-college workers in Canada for the 1981 and 2008 period.[3]

Table 1 presents data on the shares of total hours worked by four education groups in Canada. To put things into perspective, I report the same shares for the U.S. as well.[4] In 1981, the share of college graduate hours was 20% in the country. This share doubled between 1981 and 2008, reaching 38.8% at the end of the period. Meanwhile in the U.S. hours worked by college-educated increased its share from 30% to 47% , which is a slower increase compared to Canada.

Canada	**Less than High School**	**High School Graduates**	**Some College**	**College+ Graduates**
1981	32.5%	23.6%	23.9%	19.9%
1991	19.9%	21.2%	33.4%	25.3%
2001	8.4%	14.2%	48.2%	29.2%
2008	6.5%	11.5%	43.2%	38.8%
U.S.				
1980	15.4%	34.2%	19.3%	31.1%
1990	7.3%	26.8%	28.7%	37.3%
2000	6.3%	24.6%	26.4%	42.7%
2008	5.1%	22.2%	25.7%	47.0%

Table 1: Employment shares by education level in % units. Employment is measured as total hours worked by each education group

[3] Details about sample selection and the construction of skilled and unskilled categories are available in the appendix.

[4] Hereafter skilled and college-educated are used interchangeably.

In table 2, I report the change in hourly wages and hours worked by college-educated individuals relative to non-college. As pointed out in table 1 results, the ratio of skilled to unskilled hours almost doubled during 1981-2008 period. During the 1980s there was a 30% rise in this ratio. The increase in the skilled hours relative to unskilled slowed down to 19.4% in 1990s. The most remarkable increase was recorded between 2001 and 2008 where the relative share of college graduate hours increased by 43%. On the other hand there was a 17% increase in the hours worked by college graduates relative to those with no college education in the 2000s in the U.S. labor markets. The change in the ratio of hours by college graduates to non-college was 67% in the U.S. between 1981 and 2008 which is smaller than the one recorded for Canada.

College graduates	**change relative**	**change relative**
Canada	**employment share**	**wage**
1981-1991	31.2%	-1.0%
1991-2001	19.4%	1.7%
2001-2008	43.0%	0.7%
1981-2008	93.5%	1.5%
U.S.		
1980-1990	27.4%	9.8%
1990-2000	22.9%	5.5%
2000-2008	17.4%	3.8%
1980-2008	67.7%	18.9%

Table 2: % change in hours worked and the hourly wages of college graduates relative to non-college

The fast increase in the relative share of hours worked by college graduates was accompanied by a sluggish growth in their relative wages between 1981 and 2008. The college education premium displayed 1.5% increase throughout the whole period. During the 1980s, college graduates experienced a slight decline in their hourly wages relative to less than college

educated ones. 1990 to 2008 was a period of slight increase in college education premium in Canada. The U.S. exhibits a different example in terms of the dynamics of skill premium. The college-educated enjoyed a 19% increase in their relative earnings between 1980 and 2008.

Table 3 reports the skilled hours relative to unskilled for natives and immigrants. The hours worked by native college graduates relative to less than college educated increased from 19% to 42% in Canada. The college-graduate immigrants' relative hours rose faster displaying a four-fold increase from 5% to 21%. A similar pattern is observed in the U.S. as well.

	Native college/ non-college	**Immigrant college/ non-college**
1981	19.5%	5.4%
1991	27.3%	6.7%
2001	31.4%	9.8%
2008	42.1%	21.3%
U.S.		
1980	41.5%	3.5%
1990	53.6%	5.8%
2000	64.8%	9.7%
2008	74.5%	14.3%

Table 3: Hours worked by immigrant and native college graduates relative to total non-college

Decomposing the college-graduate immigrants' relative hours, I get two shares. The first one is the ratio of immigrant college to immigrant non-college hours, and the second one is the ratio of immigrant non-college to total non-college hours. In table 4, I present these two ratios. The behavior of the first ratio is of more interest since it shows the change in the skill composition among hours worked by immigrants. This ratio increased from 28% to 78% from the beginning of the 1980s until the end of the 2000s.

Canada	Immigrant college/ immigrant non-college	Immigrant non-college/ total non-college
1981	28.5%	18.9%
1991	41.5%	16.2%
2001	39.0%	25.2%
2008	78.5%	27.1%

Table 4: Decomposition of hours worked by immigrant college graduates relative total non-college

An overall analysis of the three decades shows that in Canada premium paid to college education has either declined slightly or increased very sluggishly between 1981 and 2008. The fast growth in the hours worked by college graduates relative to non-college individuals provides evidence for the possible impact of the supply side of the labor market on the stagnant behavior of skill premium in the country. In addition the remarkable shift in the composition of the foreign born workers towards skilled ones points to the importance of analyzing the impact of foreign born workers on skill premium dynamics.

2.3 QUANTITATIVE ANALYSIS

The objective in this section is to measure quantitatively how much the supply side factors in Canadian labor markets accounted for the observed dynamics in skill premium for the 1981-2008 period. While analyzing the supply side, I emphasize particularly the role of an increase in the relative share of total hours worked by skilled immigrants. The first subsection discusses the model environment. The section following that explains the calibration procedure. In the subsequent part, I present the model results for the skill premium between 1981 and 2008. In the last subsection I run some counterfactual experiments and discuss their results.

2.3.1 Model

The model is a partial equilibrium one where firms produce the final good using skilled and unskilled labor, capital equipment and capital structures a la KORV (2000)[50] as follows;

$$Y_t = A_t K_{st}^{\alpha}[\mu U_t^{\theta} + (1-\mu)\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}}]^{\frac{1-\alpha}{\theta}} \tag{2.1}$$

Define $H_t = [\mu U_t^{\theta} + (1-\mu)\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}}]^{\frac{1}{\theta}}$

Firms maximize their profits by choosing the amount of K_{et}, K_{st}, S_t and U_t they will use. The first order conditions of firms give the following wages for skilled and unskilled labor.

$r_{st} = \alpha\left(\frac{H_t}{K_{st}}\right)^{1-\alpha}$

$r_{et} = \theta\lambda(1-\mu)(1-\alpha)K_{st}^{\alpha}H_t^{-\alpha}K_{et}^{\rho-1}\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}-1}$

$r_t^s = (1-\lambda)(1-\mu)(1-\alpha)K_{st}^{\alpha}H_t^{1-\alpha-\theta}S_t^{\rho-1}\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}-1}$

$w_t^u = \mu(1-\alpha)\theta K_{st}^{\alpha}H_t^{-\alpha}U_t^{\theta-1}$

$w_t^s = \theta(1-\lambda)(1-\mu)(1-\alpha)K_{st}^{\alpha}H_t^{-\alpha}S_t^{\rho-1}\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}-1}$

The skill premium implied by the model is;

$$\frac{w_t^s}{w_t^u} = \frac{(1-\lambda)(1-\mu)}{\mu}\{\lambda K_{et}^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta-\rho}{\rho}}\frac{S_t^{\rho-1}}{U_t^{\theta-1}} \tag{2.2}$$

By taking logs of equation (2.2) and differentiating with respect to time we obtain the following for the growth rate of skill premium;

$$g_{\frac{w_t^s}{w_t^u}} \simeq (\theta-1)g_{\frac{S_t}{U_t}} + (\theta-\rho)\lambda g_{\frac{K_{et}}{S_t}}\left(\frac{K_{et}}{S_t}\right)^{\rho} \tag{2.3}$$

here g_x denotes the growth rate of the variable x.

The growth rate of the skill premium has two components, the growth rates of the relative share of skilled employment ($\frac{S_t}{U_t}$) and the capital equipment per skilled labor ($\frac{K_{et}}{S_t}$). KORV (2000)[50] identify the first component as the "relative quantity effect" and the second as the "capital-skill complementarity effect". Under the parameter restrictions that $\theta < 1$ and $\theta > \rho$, the growth rate of the skill premium increases with increases in the growth rate of capital equipment per skilled labor hours and declines with decreases in the growth rate of the relative share of skilled employment.

2.3.2 Calibration

I start the quantitative analysis by determining the parameters of the model. There are 5 parameters in the production function described in equation (2.1). These are share parameters (α, λ, μ) and the elasticity of substitution parameters (θ, ρ). I set α which is the share of capital structures to 0.13 which is the value used by Greenwood, Hercowitz and Krusell (1998).[**?**] There is range of estimates for (θ, ρ). KORV (2000)[50] use the U.S. data and estimate $\rho = -0.495$. I set the value of ρ to its value as estimated by KORV (2000).[50] μ, λ and θ are calibrated to match the average wage bill ratio, average labor share of income and the average growth rate of the skill premium between 1981 and 2008. Table 5 lists the parameters from outside sources and table 6 reports the calibrated parameters together with their data moments.

Parameter	**Source**
$\boldsymbol{\rho = -0.495}$	KORV (2000)
$\boldsymbol{\alpha = 0.130}$	Greenwood, Hercowitz and Krusell (1998)

Table 5: Parameters from outside sources

Parameter	**Moment**	**Data Value**	**Model Value**
$\boldsymbol{\theta = 0.927}$	Δ skill premium (1981-2008)	1.5%	1.5%
$\boldsymbol{\lambda = 0.939}$	Average labor share of income	62%	62%
$\boldsymbol{\mu = 0.986}$	Average wage bill ratio	48%	48%

Table 6: Calibrated parameters and moments

2.3.3 Model Results

In this section I assess the performance of the model in explaining the evolution of relative wage earnings of college graduates in Canada for the 1981-2008 period. I use the model

parameters, the actual series for machinery and equipment capital stock K_{et}, the hours worked by skilled and unskilled individuals S_t,U_t to obtain a predicted series for the college premium $\left(\frac{w_t^s}{w_t^u}\right)$,using equation (2.2).

The data series for college education premium is compared with its model counterpart in figure 1. Despite the fact that the model generated skill premium does not track each data point, overall it captures the general stagnant behavior of the relative wage earnings of college graduates between 1981 and 2008. To take a closer look at the performance of the model, I report the change in the relative earnings of skilled workers in table 7. The model predicts a slight rise by 1.7% in the skill premium between 1981 and 1991. In the data, the college-educated individuals experienced a slight decline in their relative earnings by 1%. For the 1991-2001 period, skill premium displays 1.7% increase and the model predicts this increase to be around 1% explaining around 56% of the slight increase observed in the data. During the 2000s, the premium enjoyed by college-educated individuals remained almost constant in Canada with a slight increase of 0.7% whereas the model predicts a slight decline of -1.2% for that period. Although the predictions of the model for the direction of the change in college premium are not the same as in the data for the 1981-1991 and 2001-2008 periods, since the magnitude of the change is very small both in the data and the model, I can say that the model also does well in generating the sluggish movement of the college premium for those periods.

	Data	**Model**
1981-1991	-1.0%	1.7%
1991-2001	1.7%	1.0%
2001-2008	0.7%	-1.2%

Table 7: % change in the relative wage earnings of college graduates. Model vs. data

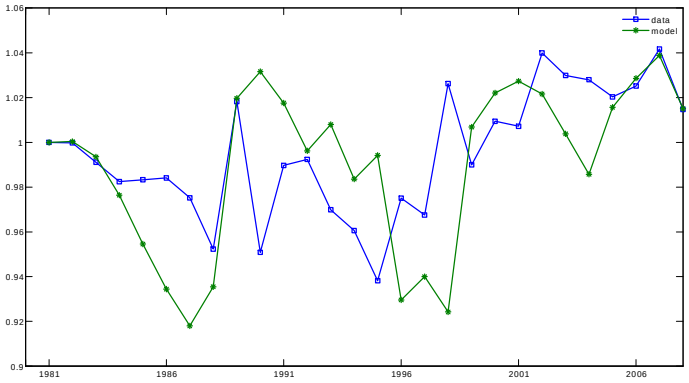

Figure 1: Skill Premium 1981-2008: Model vs. data

To further analyze the dynamics of skill premium, I decompose the growth rate of skill premium using equation (2.3). In the model the skill premium increases by nearly 1.5% between 1981 and 2008. Decomposition of the change in skill premium shows that of the total change, -6.8% is due to the increase in the relative share of college and above educated workers. This implies that the capital skill complementarity worked in the opposite direction. In other words, the machinery and equipment stock increased at a faster rate than the college-educated workers. This observed increase in machinery and equipment stock compensated for the negative impact of the relative quantity effect on the skill premium.

An essential question to ask at his point is how much the inflows of highly educated immigrants took part in the decline in the skill premium. To find this out, I further decompose the relative quantity effect into its native and foreign born components as follows[5];

$$\Delta(\frac{S_T}{U_T}) = \Delta(\frac{S_M}{U_T})\frac{S_M}{S_T} + \Delta(\frac{S_N}{U_T})\frac{S_N}{S_T}$$

Here S_T denotes the total hours by skilled labor, S_M is the hours worked by foreign born skilled labor and S_N is that by native skilled labor. The results of the decomposition exercise summarized in table 9 show that the increase in college-educated immigrants contribute 35% to the growth in the relative share of skilled labor and the decline in college premium between

[5]Details of the decomposition are in the appendix

1981 and 2008. The increase in the relative share of native skilled is responsible for the remaining 65% of the growth in the share of skilled labor and the decline in skill premium between 1981 and 2008.

Growth rate components	
$\mathbf{g}_{\frac{K_e}{S}}$	0.22
$\mathbf{g}_{\frac{S}{U}}$	0.93
Relative quantity effect	-0.07
Capital-skill complementarity effect	0.08

Table 8: Decomposition of the growth rate of skill premium

	Δ (log points)	Contribution (log points)	Contribution (%)
Total college/total non-college	0.93		
Native college/total non-college	0.78	0.61	65%
Immigrant college/total non-college	1.38	0.32	35%

Table 9: Decomposition of the growth rate of college graduate hours relative to non-college

2.3.4 Counterfactual Scenarios

The objective in this section is to solve the model for Canada under some counterfactual scenarios and observe the behavior of college education premium. The counterfactual scenarios are designed so as to understand how the change in the relative supply of college hours among immigrants affected the dynamics of skill premium. To accomplish this goal, I conduct two counterfactual experiments and simulate the model. The counterfactual scenarios considered answer the following questions;

How would the skill premium in Canada evolve if

1. the share of skilled hours among immigrants did not increase between 1981 and 2008
2. the share of skilled hours among immigrants grew at the same rate as in the U.S.

Table 10 reports the relative share of hours worked by college graduates under the counterfactual scenarios. Under the first counterfactual scenario, the increase in the relative share of college graduate hours between 1981 and 2008 is 28% points lower than in the data. In the second counterfactual economy where the relative share of college graduate hours among immigrants increases at the same rate as in the U.S., the ratio of college-graduate to non-college hours displays a 78% for the whole period. This is 15% points lower than the one observed in the data. 2001-2008 is the period during which the ratio of hours worked by college graduate to non-college immigrants increased the fastest, therefore the biggest difference in the growth rate of the relative college hours between the real and counterfactual data occurs between those years.

	Data	**Scenario 1**	**Scenario 2**
1981-1991	31.2%	24.4%	27.9%
1991-2001	19.4%	19.4%	26.2%
2001-2008	43.0%	21.8%	24.7%
1981-2008	93.5%	65.7%	78.8%

Table 10: Change in relative share of college graduate hours under counterfactual scenarios

Going back to equation (2.3), the slower growth in college graduate hours relative to non-college hours affects the change in college education premium through two different channels. Firstly a smaller growth rate in the ratio of skilled to unskilled labor pulls up the pace at which the relative wage earnings of the highly educated increases. This is the relative quantity channel. Secondly as skilled hours increase more slowly relative to unskilled, the machinery and equipment stock per skilled labor rises at a faster rate. This is the capital-skill complementarity effect which reinforces the increase in college education premium.

The growth rate of college education premium is compared with the benchmark model in

table 11. The results of the counterfactual scenario 1 report the change in college education premium had the relative share of skilled hours among the foreign born labor force stayed constant between 1981 and 2008. For all the decades between 1981 and 2008, the growth rate of college education premium is higher than its data counterpart. The model predicts that the college education premium will increase by nearly 9.7% as opposed to the 1.5% change observed in the data when there is no change in the composition of hours worked by immigrants. The results for the counterfactual scenario 2 are similar. If the growth rate in the relative share of skilled among the foreign born in Canada were the same as in the U.S., the relative wage earnings of college graduates would grow by 5.9% throughout the whole period. This is a 4.5% points improvement over the growth rate of skill premium observed in the data which accounts for 25% of the difference in growth rates of college education premium between the two countries for the 1981 and 2008 period.

In both counterfactual scenarios there is an improvement in the sluggish behavior of the college education premium which implies that the shift in the composition of immigrants more towards college graduates had impacts on the relative return to higher education in Canadian labor markets between 1981 and 2008.

Looking at each period separately during the first decade, skilled wages increase fastest under the counterfactual scenario 1. The rise in college education premium when there is no change in the composition of immigrant hours, is around 2 times more than the one predicted by the benchmark model. For the 1991-2001 period the change in relative hours of college graduates observed in the data is almost the same as the one under the first counterfactual case, which leads to a slow rise in skill premium comparable to its benchmark model value. The most significant discrepancy between the predictions of the benchmark model and counterfactual scenarios for the change in skill premium is observed during the 2001-2008 period. With no change in the skill composition of hours worked by immigrants, the ratio of college to non-college hours increases by 22% instead of 43% as in the data. With a smaller relative quantity effect, the skill premium grows by 4.6%. This implies a 6% points improvement in college education premium compared to the benchmark model. Similarly with the U.S. growth rate in the relative share of skilled to unskilled hours among immigrants, the skill premium displays a 4% increase stemming from a slower growth in

relative skilled hours.

	Model	Scenario 1	Scenario 2
1981-1991	1.7%	3.9%	2.7%
1991-2001	1.0%	1.2%	-0.9%
2001-2008	-1.2%	4.6%	4.1%
1981-2008	1.5%	9.7%	5.9%

Table 11: Change in college education premium under counterfactual scenarios

2.4 CONCLUSION

Wage inequality between college graduates and the non-college has remained either stagnant or declined in Canada between 1981 and 2008. This stagnant behavior of the college premium is accompanied by an increase in skilled hours relative to unskilled. The increasing weight of college graduates among total hours worked by immigrants is an important factor contributing to the increase in the hours worked by college graduates. In this paper I make a quantitative analysis of the impact of the growth in skilled hours among immigrants on the college education premium in the country.

The model is a partial equilibrium one where firms produce output using skilled and unskilled labor as well as two different types of capital - structures and capital - a la KORV (2000)[50]. In the quantitative analysis part I use this production function, real stock of machinery and equipment adjusted for quality changes and the composition adjusted hours worked by college graduates and those with less than college education as skilled and unskilled labor inputs and show that I can track the general stagnant behavior of college education premium in Canada.

Having established the success of the model in explaining the overall dynamics of the relative earnings of skilled workers, I simulate two counterfactual cases to evaluate the impact of the rise in the share of college graduates among immigrants. The first counterfactual

scenario simulates an economy where the skill composition of immigrants stays at its 1981 level throughout the whole period. The results of this counterfactual experiment shows that with no change in the share of hours worked by college-educated among immigrants, the growth rate in skill premium is nearly 6 times higher than the one observed in the data. The impact is especially remarkable for the 2001-2008 period which exhibits the fastest growth in the skilled employment hours among immigrants. The relative wage earnings of college-educated individuals increase by 4.6% as opposed to the -1.2% decline in this counterfactual economy. The second counterfactual scenario illustrates the Canadian economy in which the skill composition of hours worked by immigrants grows at the same rate as in the U.S. College education premium increases by 5.9% between 1981 and 2008 in this case. Compared to the data, this is a 4.5% points improvement in the relative wage earnings of college graduates. This implies that the difference between the growth in skilled hours among immigrants experienced by two countries accounts for around 25% of the 17% points larger increase in U.S. college premium.

The partial equilibrium modelling approach in this paper does not allow for changes that might occur in the capital stock or skilled and unskilled labor in response to exogenous shifts in the immigrant labor force. Analyzing the impacts of immigration in a general equilibrium setting where the savings and education choices are endogenously determined is an interesting extension of the model which is planned as future work.

3.0 IMMIGRATION IN CANADA: A GENERAL EQUILIBRIUM ANALYSIS

3.1 INTRODUCTION

Immigration is a highly debated issue among policy makers, researchers, and the public. The immigrants' impact on the native population of a country has been evaluated in many aspects including wage and overall welfare changes as well as the burden or relief they create for the fiscal system.[1] The objective of this paper is to quantify the effects of immigration on Canada's native population using a general equilibrium model.

There are two remarkable features of Canada's immigrant population. The first one is that they constitute an important proportion of the total population and their share among the total population has been increasing. According to 2006 Canadian Census data, the foreign born constituted almost 20% of the total population, a 5% points increase since the beginning of the 1980's.[2] The second distinguishing feature of the immigrant population in Canada is the increase in the relative share of college-educated individuals. The increase in the proportion of college graduates among the immigrant population is an outcome of the selective immigration policy enacted in 1967. The 1967 Immigration Act introduced the points system as a tool to select immigrants into the country. In a points system, immigrants are admitted to the country based on the points they collect according to their education, age, language and other qualifications.[3] Soon after the implementation of the new policy,

[1] Card, D. (1990, 2001), Altonji, J., Card, D. (1991), use spatial approaches to estimate the impacts of immigrants on the wage and employment of natives in the U.S. Borjas, G. (1994,2003), Borjas, G., Freeman R., Katz, L. (1992, 1996, 1997), Aydemir, A., Borjas, G. (2007) are nationwide analyses of the labor market impacts of immigration. Storesletten (2003) evaluates the fiscal impacts of immigrants.

[2] Immigration in Canada: A Portrait of the Foreign-Born population, 2006 Census.

[3] Green, Alan G., Green, David A: *"The Economic Goals of Canada's Immigration Policy: Past and*

there was an increase in the share of the highly educated among the immigrant population in Canada. A comparison of the intended occupational groups of the incoming immigrants in 1966 and 1977 shows that the total share of professional and managerial workers and clerical, commercial and financial laborers increased from 43% to 52% between those years. These are the occupation groups which require the highest level of education.[4]

A rigorous evaluation of the post 1967 immigration experience of Canada in terms of how it affects the welfare, income, and human and physical capital of natives is important since a similar candidate immigration policy is being considered in other developed countries. The most recent example of such countries is France. In 2007, a new immigration law which gives the government new powers to encourage high skilled immigration took effect in the country. Among the main objectives of the new policy are recruiting skilled workers, facilitating foreign students' stay and tightening the rules on family reunification.[5]

To analyze the impacts of immigration, I develop a heterogenous agent OLG model in the tradition of Auerbach and Kotlikoff (1987)[3]. Native individuals are heterogenous with respect to their ability levels, and they make a discrete college decision at the beginning of their lives in the model. The ability level of a native individual determines his schooling decision as well as the efficiency units of labor he provides as either a skilled or an unskilled worker. Immigration affects the native population through its direct and indirect impacts on prices and the tax rate in the economy. For example an influx of immigrants which increases the proportion of college graduates among the immigrant population, as in Canada, is a positive supply shock to college-educated labor, which decreases the wage level for this group. On the other hand, unskilled labor and physical capital become relatively more scarce, therefore the return on these factors increases.

Immigration also alters the factor returns indirectly through two channels. The first is the human capital channel. The inflow of skilled immigrants discourages some natives from enrolling in college and leaves only the higher ability ones with a college education. In other words, both the number and the average ability level of skilled and unskilled labor

Present"

[4]Source: *Citizenship and Immigration Canada. http://www.cic.gc.ca, Citizenship and Immigration Statistics Archives.*

[5]*Source: Murphy, Kara. "France's New Law: Control Immigration Flows, Court the Highly Skilled". Migration Policy Institute, November 2006.*

change in response to an increase in the proportion of college-graduate immigrants. Another indirect channel through which immigration affects prices is the physical capital channel. Immigrants arrive in the country with low asset holdings, so their inflow dilutes the physical capital stock.[6] The lower per capita physical capital changes the interest rates, hence the saving decision of natives.

In my quantitative analysis, I evaluate the impact of changes in the immigrant population that took place in Canada between 1981 and 2008. I run two counterfactual experiments to assess the implications of an increase in the share of immigrants and the shift in their composition towards college graduates for the native population. My findings suggest that an increasing share of immigrants with a shift in their composition, as observed in Canada, results in a decline in the college attainment rate among natives. The results from the counterfactual experiments show that the increase in the relative share of college graduates among immigrants is the main reason for natives being discouraged from college education. Almost 7 in every 100 native Canadians opt out of college education due to the change in the composition of the immigrant population. Besides decreasing enrollment in college education, the model predicts that immigration accounts for around 2% of the increase in the college premium among natives between 1981 and 2008. Interestingly, the shift in the composition of immigrants towards college graduates alone increases the college premium slightly. This result is different from the results of the static models which predict that the inflow of highly educated immigrants to Canada decreases the wage inequality between college graduates and those with less than college education in the country.[7] The reason for this difference is the reoptimization of the schooling decision by natives. The decline in college attainment among natives in response to having more college-educated immigrants offsets the negative impact of the shift in the composition of immigrants on the relative earnings of college graduates. This is due to the fact that a smaller share of the native population with a higher average ability remains as college graduate.

The overall impact of immigration on the native population are also evaluated by quantifying its welfare effects. The welfare analysis in the paper first compares the 2008 econ-

[6] The median amount of savings by all immigrants in 2001 is reported as $15,000. *Source: Longitudinal Survey of Immigrants to Canada : A Portrait of Early Settlement Experiences (2005)*

[7] See Aydemir and Borjas (2007).

omy with a counterfactual one in which the immigrant population keeps its 1981 share and composition. Unlike Borjas (1994)[11], which predicts an immigration surplus accruing to natives, I find that the change in the immigrant population created a welfare loss for natives in Canada. Based on the results of counterfactual experiments, I conclude that the main driver of the welfare loss is the increase in the size of the immigrant population. On the other hand, the shift in the composition of immigrants towards college graduates creates a small net welfare gain to natives, which amounts to an approximately 0.02% increase in the permanent consumption of both college graduate and high school graduate natives at the top, bottom and middle of the ability distribution.

A brief look at the literature that studies the impacts of immigrants on the earnings of natives shows that there is conflicting evidence. The spatial approach makes use of the variation in the immigrant inflows in local labor markets to estimate the impacts of immigration. Altonji and Card (1991)[2] treat immigrants and natives as two factors of production, whereas Card (1990, 2001)([21],[22])assume that immigrants and natives of the same skill group are perfect substitutes. These studies find a small impact of immigrants on the wages of natives. On the other hand, research that use a nation-wide approach find significant and negative impacts of immigration on native earnings. For instance, Borjas, Freeman, and Katz (1997)[14] and Borjas (2003)[13] estimate the impact of immigration on natives of different education and experience groups. These studies find a larger and negative impact of immigration on the wage earnings of the natives. Similarly, Aydemir and Borjas (2007)[5] compare the impact of immigration induced labor supply shocks on the relative earnings of natives in different education groups in the U.S., Canada, and Mexico. Their results suggest that the immigration experience of Canada narrowed the wage inequality due to the high proportion of skilled immigrants. For the U.S., they conclude that the wage inequality increased as a result of immigration since the immigrant population consists more of low-skilled individuals.

In addition to these studies, there are several which evaluate the effects of immigration with a general equilibrium model. Ben-Gad (2004, 2008)([7],[8]) find the wage and welfare impacts of immigration to be lower than the static models. Storesletten (2003)[73] analyzes the fiscal impacts of different education levels of immigrants and concludes that high skilled

immigration can be used to ease the fiscal burden of an ageing population. A common feature of these papers is that physical capital is endogenous; however, human capital is either absent or exogenous. Heckman, Lochner and Taber (1998)[42] investigate the role of immigration in explaining the increasing wage inequality observed in the U.S. during the 1980's. They extend the Ben-Porath framework by adding heterogeneous agents and endogenous human capital accumulation. Their results suggest that immigration does not have a significant impact on wage inequality. Eberhard (2011)[31] develops a model with endogenous human capital but he precludes physical capital in his setting. He finds that unexpected immigration shocks have a positive and larger impact on the earnings of individuals through human capital accumulation and educational attainment of natives compared to a smaller and negative direct effect. My paper is different from these two papers in the way human capital choice is modeled. In both Heckman et al. (1998)[42] and Eberhard (2011)[31], the human capital decision is a continuous one, whereas in my model individuals of different ability levels make a discrete college decision. This specification allows me to compare the college attainment rates in the model with the data and assess immigrants' impact on the education decision of natives in the economy.

The remainder of the paper is organized as follows. Section 3.2 discusses the data and section 3.3 describes the model. In section 3.4, parameters of the model are explained. Section 3.5 contains the results of the calibration and the benchmark economy in 1981. The following section discusses the counterfactual experiments and section 3.7 offers a conclusion.

3.2 DATA

In this section, I present some data for the 1981-2008 period.[8] As mentioned previously, there are two important observations about the immigrant population in Canada. The first one is the increase in the relative share of immigrants among the total population. The

[8] I make use of two different micro data sets for my analysis. The first one is the Survey of Consumer Finances (SCF), which contains information on individuals aged 15 years and over for the 1981-1997 period. The second one is the Survey of Labor and Income Dynamics (SLID), which covers the 1993-2008 period. The sample consists of employed wage and salary workers between ages 18 and 65, and retired individuals above 65. I am interested in immigrants who have acquired all their education before arriving in Canada therefore, I exclude immigrants below age 22 from my sample.

second one is the simultaneous shift in the immigrant population towards college graduates. Table 12, panel A reports the relative share of the immigrants in the sample as well as the proportion of college graduates among the immigrants.[9]

Panel A: Stock of immigrants

	Relative share of immigrants		% college graduate immigrants	
	Canada	U.S.	Canada	U.S.
1981	20%	7%	12%	17%
1991	18%	9%	17%	21%
2001	28%	12%	18%	25%
2008	31%	15%	30%	27%

Panel B: Inflows of immigrants

Entry period	% college graduate immigrants
1961-1971	14%
1971-1981	18%
1981-1991	20%
1991-2001	36%
2000-2008	44%

Table 12: Stock and flow of immigrants

Between 1981 and 2008, the relative share of immigrants among the sample increased from 20% to 30%. The increase in the share of immigrants occurred mostly after the 1990's. On the other hand, the increase in the relative share of college graduates among immigrants happened throughout the whole period. College-graduate immigrants constitute 12% of immigrants in the 1981 sample. The same ratio is 30% for the 2008 sample of immigrants. Comparing these numbers with the U.S. data shows that in Canada, immigrants are a greater proportion of the total population and the relative share of college graduates increased at a faster rate between 1981 and 2008.

[9]More detailed information about how the two education groups-college graduates and less than college graduates- are constructed both for SCF and SLID data is provided in the appendix.

Panel B presents the relative share of college graduates among the immigrants that inflow to the economy in the designated periods. Among the immigrants that came to Canada between 1961 and 1971, 14% were college graduates. This ratio increased to 44% among the immigrants who entered the country between 2000 and 2008. This fact illustrates a shift in the educational profile of immigrants towards more college graduates in the country.

One objective of this paper is to assess the impacts of observed changes in the immigrant population on the wage earnings of natives. In particular, I am interested in how the shift in the composition of the immigrant labor force affected the relative earnings of college-graduate natives in the country. Table 13 below reports the relative share of college graduates among the native population and the college premium. The college premium in the country increased by nearly 8% between 1981 and 2008. Meanwhile the share of college graduates among the native population also increased from 8.6% to 24.4%. A relevant question to ask here is how much of an impact immigration in Canada had on the relative earnings of college graduates and their share among the natives.[10]

	College premium	% college graduates
1981	0.34	8.6%
1991	0.36	13.3%
2001	0.39	19.4%
2008	0.42	24.4%

Table 13: Log wage gap between college graduate and less than college graduate natives and the share of college graduates among natives

[10]The college premium among natives is calculated using full-time full-year wage and salary workers between ages 18 and 65. I follow Autor, Katz and Kearney (2008) definition of 40+ weeks in a year, for full year workers. 30+ hours of work per week is the criterion for a full time worker based on Statistics Canada's definition (http://www.statcan.gc.ca/pub/71-222-x/2008001/glossary-glossaire-eng.htm#a21) Workers with an hourly wage of less than $1 are also dropped from the sample. To compute the college premium, I regress log hourly wages on age, age-squared, a sex dummy and a dummy variable indicating whether the individual is a college graduate or not. The college premium is measured as the coefficient of the college graduate dummy in this regression.

3.3 MODEL

The model is a 68 period OLG model which incorporates the discrete college education decision of individuals in an environment where there is investment specific technological change and immigration flows. The natives are heterogeneous with respect to innate ability. The ability level of an individual affects his college decision and the human capital he will provide in the labor market. Individuals make their college choice in period 1 of their lives, which corresponds to age 18. They retire at the age of 65 and die when they are 85.

3.3.1 Individual's Problem

Preferences

Natives

An individual born at time t chooses $\{c_{j,s}^{n,e}, k_{j+1,s+1}^{n,e}\}$ to maximize the discounted value of life time utility given by

$$\max_{\{c_{j,s}^{n,e}, k_{j+1,s+1}^{n,e}\}} \sum_{j=1}^{J} \beta^{j-1} u(c_{j,s}^{n,e}) \tag{3.1}$$

subject to his budget constraints.

The index $j = 1, ..J$ denotes the age, n denotes nativity status, $e \in \{c = college\ graduate,\ h = high\ school\ graduate\}$ indicates the education level of the individual and $s = t + j - 1$ is the time index.

Each individual chooses whether or not to go to college at the beginning of his life. If he chooses $e = h$, he starts working immediately until the retirement age j^*. If he chooses to go to college, he spends the first four years at school, then starts working as a skilled worker. Accordingly, for $e = c$, the budget constraints of the individual born at time t are

$$c_{j,s}^{n,c} + k_{j+1,s+1}^{n,c} + T_s \leq ((1 - \tau_k)(r_s - \delta) + 1))k_{j,s}^{n,c} \quad for\ j = 1, ..4, \tag{3.2a}$$

$$c_{j,s}^{n,c} + k_{j+1,s+1}^{n,c} \leq ((1 - \tau_k)(r_s - \delta) + 1))k_{j,s}^{n,c} + (1 - \tau_l) w_s^c a \varepsilon_j^{n,c} for\ j = 5, ..j^* \tag{3.2b}$$

$$c_{j,s}^{n,c} + k_{j+1,s+1}^{n,c} \leq ((1-\tau_k)(r_s - \delta) + 1))k_{j,s}^{n,c} + b_{j,s}^{n,c} \quad for\ j = j^* + 1, ...J. \tag{3.2c}$$

for $e = h$ the budget constraints are

$$c_{j,s}^{n,h} + k_{j+1,s+1}^{n,h} \leq ((1-\tau_k)(r_s - \delta) + 1))k_{j,s}^{n,h} + (1-\tau_l)w_s^h a\varepsilon_j^{n,h} \ for\ j = 1, ..j^* \tag{3.3a}$$

$$c_{j,s}^{n,h} + k_{j+1,s+1}^{n,h} \leq ((1-\tau_k)(r_s - \delta) + 1))k_{j,s}^{n,h} + b_{j,s}^{n,h} \ for\ j = j^* + 1, ...J. \tag{3.3b}$$

I define $b_j^{n,h}$ as the social security benefits, $\varepsilon_j^{n,c}, \varepsilon_j^{n,h}$ as the age specific efficiencies for the two education groups, and r, w^c, w^h as returns on capital, and two types of labor, τ_k and τ_l as tax rates on capital and labor income. T is the tuition cost that an individual needs to pay to get college education.

Immigrants

Similar to Heckman et al. (1998)[42], immigrants are assumed to enter the economy past their schooling age.[11] I assign an average ability level $\overline{a}_m^c$ and $\overline{a}_m^h$ to college-graduate and less than college-educated immigrants and exempt from an ability distribution among them. Based on these, the life-time utility maximization problem of an immigrant who enters the economy in period t is given by

$$\max_{\{c_{j,s}^{m,e}, k_{j+1,s+1}^{m,e}\}} \sum_{j=23}^{J} \beta^{j-1} u(c_{j,s}^{m,e})$$

subject to his budget constraints. Here the time index is $s = t + j - 23$ and m indicates that the individual is an immigrant. The budget constraints of a college graduate immigrant are

$$c_{j,s}^{m,c} + k_{j+1,s+1}^{m,c} \leq ((1-\tau_k)(r_s - \delta) + 1)k_{j,s}^{m,c} + (1-\tau_l)w_s^c \overline{a}_m^c \varepsilon_j^{m,c} \quad for\ j = 23, ..j^* \tag{3.4a}$$

$$c_{j,s}^{m,c} + k_{j+1,s+1}^{m,c} \leq ((1-\tau_k)(r_s - \delta) + 1)k_{j,s}^{m,c} + b_{j,s}^{m,c} \ for\ j = j^* + 1, ...J \tag{3.4b}$$

[11] For simplicity, I assume that all immigrants that inflow to the economy are at age 40 which corresponds to age 23 in the model. This is the median age of a sample of immigrants above age 22 in the data which is constant between 1981 and 2008.

Similarly the budget constraints of an immigrant with less than college education take the form

$$c_{j,s}^{m,h} + k_{j+1,s+1}^{m,h} \leq ((1-\tau_k)(r_s - \delta) + 1)k_{j,s}^{m,h} + (1-\tau_l)w_s^h \overline{a}_m^h \varepsilon_j^{m,h} \quad for\ j = 23, ..j^* \tag{3.5a}$$

$$c_{j,s}^{m,h} + k_{j+1,s+1}^{m,h} \leq ((1-\tau_k)(r_s - \delta) + 1)k_{j,s}^{m,h} + b_{j,s}^{m,h} \ for\ j = j^* + 1, ...J \tag{3.5b}$$

Schooling Choice

Natives

In the model, natives make a discrete college decision at the beginning of their lives. This decision is made by comparing the lifetime utility of being a college graduate and that of remaining a high school graduate.

Let $V_{j,t}^e(a, k_{j,t}^{n,e})$ denote the value of lifetime utility of a native individual who is j years old at time t. If the individual is a college graduate ($e = c$), the recursive representation of his utility maximization problem is as follows

$$V_{j,s}^c(a, k_{j,s}^{n,c}) = \max_{\{c_{j,s}^{n,c}, k_{j+1,s+1}^{n,c}\}} u(c_{j,s}^{n,c}) + \beta V_{j+1,s+1}^c(a, k_{j+1,s+1}^{n,c})$$

for $s = t + j - 1$ subject to equations (3.2a-3.2c)

If the individual opts not to enroll in college ($e = h$), then the corresponding value function to his lifetime utility maximization problem is

$$V_{j,s}^h(a, k_{j,s}^{n,h}) = \max_{\{c_{j,s}^{n,h}, k_{j+1,s+1}^{n,h}\}} u(c_{j,s}^{n,h}) + \beta V_{j+1,s+1}(a, k_{j+1,s+1}^{n,h})$$

subject to equations (3.3a) and (3.3b).

Individuals solve their perfect foresight utility maximization problem using backward induction. Going back to age 1, the college choice of an individual with ability level a can be characterized by the following conditions

$$V_{1,t}^c(a, k_{1,t}^{n,c}) > V_{1,t}^h(a, k_{1,t}^{n,h}) \text{ choose } e = c,$$

$$V_{1,t}^h(a, k_{1,t}^{n,h}) > V_{1,t}^c(a, k_{1,t}^{n,c}) \text{ choose } e = h \tag{3.6}$$

$$V^h_{1,t}(a, k^{n,h}_{1,t}) = V^c_{1,t}(a, k^{n,c}_{1,t}) \text{ indifferent}$$

There is a unique threshold ability level a^*_t which makes an individual indifferent between getting a college education and remaining a high school graduate $\forall t$.

3.3.2 Demographics

In each period, a new birth cohort of natives enters the economy. The new born natives replace the old cohort who left the economy one period before. I_t is the inflow of immigrants in period t. I denote the the time t native population stock of age j by $N_{j,t}$, the immigrant population stock of age j by $M_{j,t}$, and the total population by P_t. Using these I get the following equations for the law of motion for population.

$$N_{1,t+1} = N_{J,t} + M_{J,t}$$

$$M_{23,t+1} = I_{t+1}$$

$$P_t = \sum_{j=1}^{J} N_{j,t} + \sum_{j=23}^{J} M_{j,t}$$

$$P_{t+1} = P_t + I_{t+1} \tag{3.7}$$

The shares of immigrants and natives of all ages are defined as follows;

$$n_{j+1,t+1} = \frac{N_{j+1,t+1}}{P_{t+1}} = \frac{n_{j,t}}{(1+i_{t+1})},\ n_{1,t+1} = \frac{n_{J,t} + m_{J,t}}{(1+i_{t+1})}\ \forall j = 1, ..J-1 \tag{3.8}$$

$$m_{j+1,t+1} = \frac{M_{j+1,t+1}}{P_{t+1}} = \frac{m_{j,t}}{(1+i_{t+1})},\ m_{23,t+1} = \frac{i_{t+1}}{(1+i_{t+1})}\ \forall j = 23, ..J-1 \tag{3.9a}$$

where $i_{t+1} = \frac{I_{t+1}}{P_t}$

Using the definition of age shares of immigrants, the share of college-graduate and less than college-graduate immigrants at each age are given by;

$$\begin{aligned} m^c_{j,t} &= \varkappa^c_{t-j+23} m_{j,t} \\ m^h_{j,t} &= \varkappa^h_{t-j+23} m_{j,t}\ \forall j = 23, ..J-1 \end{aligned}$$

where $\varkappa^c_{t-j+23}$ and $\varkappa^h_{t-j+23}$ denote the share of college graduates and less than college graduates among median age immigrants who arrived in period $(t-j+23)$, respectively.

3.3.3 Firm's Problem

3.3.3.1 Production Technology The production technology in the model has the feature of complementarity between skilled labor and capital equipment a la Krusell, Ohanian, Rios-Rull and Violante (2000)[50]. The production function is a nested CES aggregate of skilled and unskilled labor and capital as follows

$$Y_t = [\mu U_t^{\theta} + (1-\mu)\{\lambda(K_t)^{\rho} + (1-\lambda)(S_t)^{\rho}\}^{\frac{\theta}{\rho}}]^{\frac{1}{\theta}} \tag{3.10}$$

In this setting, $\rho < \theta$ implies a complementarity between capital and skilled labor and $(\theta - \rho)$ measures the degree of complementarity.

The law of motion for the physical capital stock in the economy is;

$$K_{t+1} = (1-\delta)K_t + I_t q_t$$

Here q_t represents the state of the technology for producing physical capital and it determines the amount of capital which can be purchased with one unit of consumption good. Hence $1/q_t$ is the relative price of physical capital in terms of the consumption good.

An alternative formulation of the environment with declining relative price of equipment has been developed by Greenwood, Hercowitz and Krusell (1997)[34]. In this alternative formulation, the relative price of capital equipment is constant but its productivity is increasing over time. Using transformed variables, the law of motion for capital equipment and the production function is given by;

$$\widetilde{K}_{t+1} = (1-\widetilde{\delta})\widetilde{K}_t + I_t \quad where\ (1-\widetilde{\delta}) = (1-\delta)\frac{q_{t-1}}{q_t}, and\ \widetilde{K}_t = \frac{K_t}{q_{t-1}}$$

The production function can be rewritten as;

$$Y_t = [\mu U_t^{\theta} + (1-\mu)\{\lambda(\widetilde{K}_t)^{\rho}(q_{t-1})^{\rho} + (1-\lambda)(S_t)^{\rho}\}^{\frac{\theta}{\rho}}]^{\frac{1}{\theta}} \tag{3.11}$$

The firm's profit maximization problem gives the following first order conditions;

$$r_t = \lambda\,(1-\mu)\,\widetilde{K}_t^{\rho-1} Y_t^{1-\theta}(q_{t-1})^{\rho}\{\lambda(q_{t-1}\widetilde{K}_t)^{\rho} + (1-\lambda)S_t^{\rho}\}^{\frac{\theta}{\rho}-1}$$

$$w_t^c = (1-\mu)(1-\lambda)Y_t^{1-\theta}\{\lambda(q_{t-1}\widetilde{K}_t)^{\rho} + (1-\lambda)S_t{}^{\rho}\}^{\frac{\theta}{\rho}-1} S_t^{\rho-1} \tag{3.12}$$

$$w_t^h = \mu Y_t^{1-\theta} U_t^{\theta-1}$$

3.3.3.2 Aggregation of Human and Physical Capital The production technology in equation (3.11) uses skilled and unskilled labor as well as capital equipment to produce output. Skilled labor is the aggregate human capital by college graduates and unskilled labor is the aggregate human capital by individuals who have less than a college education. The formulation of aggregate skilled labor is

$$S_t = \sum_{j=5}^{j^*} N_{j,t} \int_{a^*_{t-j+1}}^{\infty} a f(a) da + \sum_{j=23}^{j^*} M^c_{j,t} \overline{a}^c_m \tag{3.13}$$

Individuals with less than college education start working immediately. Hence the human capital provided by these individuals is

$$U_t = \sum_{j=1}^{j^*} N_{j,t} \int_{0}^{a^*_{t-j+1}} a f(a) da + \sum_{j=23}^{j^*} M^h_{j,t} \overline{a}^h_m \tag{3.14}$$

Aggregate physical capital at time t is equal to the sum of age-specific assets by natives and immigrants i.e.

$$K_t = K_t^N + K_t^M \quad where \tag{3.15}$$

$$K_t^N = \sum_{j=2}^{J} N_{j,t} \int_{a^*_{t-j+1}}^{\infty} k^n_{j,t}(a) f(a) da + \sum_{j=2}^{J} N_{j,t} \int_{0}^{a^*_{t-j+1}} k^n_{j,t}(a) f(a) da$$

$$K_t^M = \sum_{j=23}^{J} M^c_{j,t} k^m_{j,t} + \sum_{j=23}^{J} M^h_{j,t} k^m_{j,t} \tag{3.16}$$

3.3.4 Government

3.3.4.1 Social Security I follow Imrohoroglu, Imrohoroglu and Joines (1999)[48] and Chen, Imrohoroglu, Imrohoroglu (2007)[24] and assume that each individual receives a certain portion (ψ) of their average life time wage income as social security benefits. Accordingly the social security benefits of a native individual during his retirement years is as follows

$$b^{n,e}_{j',t+j'-1} = \left.\begin{array}{c} \psi \frac{1}{j^*} \sum_{j=1}^{j^*} w^h_{t+j-1} a\varepsilon^{n,h}_j \text{ if e} = h \\ \psi \frac{1}{j^*-4} \sum_{j=5}^{j^*} w^c_{t+j-1} a\varepsilon^{n,c}_j \text{ if e} = c \end{array}\right\} for\ j' = j^*+1, ..J$$

For immigrants, the same social security income is defined as

$$b^{m,e}_{j',t+j'-23} = \left.\begin{array}{c} \psi \frac{1}{j^*-22} \sum_{j=23}^{j^*} w^h_{t+j-1} \overline{a}^h_m \varepsilon^{m,h}_j \text{ for high school graduates} \\ \psi \frac{1}{j^*-22} \sum_{j=23}^{j^*} w^c_{t+j-1} \overline{a}^c_m \varepsilon^{m,c}_j \text{ for college graduates} \end{array}\right\} for\ j' = j^*+1, ..J$$

The social security program is funded by the government. Tax revenue is used to finance the social security payments and government expenditures. The government's budget equation is expressed in equation (3.17) below.

$$G_t + B_t = \tau_l(w^c_t S_t + w^h_t U_t) + \tau_k(r_t - \delta)K_t \tag{3.17}$$

where

$$\begin{aligned} G_t &= \xi Y_t \qquad (3.18) \\ B_t &= \sum_{j'=j^*+1}^{J} \{ n^h_{j',t} \int_0^{a^*_{t-j'+1}} b^{n,h}_{j',t}(a) f(a) da + n^c_{j',t} \int_{a^*_{t-j'+1}}^{\infty} b^{n,c}_{j',t}(a) f(a) da \\ &\quad + m^h_{j',t} b^{m,h}_{j',t} + m^c_{j',t} b^{m,c}_{j',t} \} \end{aligned}$$

3.3.5 Definition of Equilibrium

Given the exogenous share of each age group among natives $\{n_{j,t}\}$ and immigrants $\{m_{j,t}\}$, government policy parameters $\{\xi, \psi, \tau_l, \tau_k\}$, the exogenous price of capital equipment relative to consumption goods $\{q_t\}$, and college tuition fees $\{T_t\}$, a competitive equilibrium is represented by a sequence of factor returns $\{w_t^c, w_t^h, r_t\}$ and a threshold ability level $\{a_t^*\}$, consumption and saving choices of all individuals $\{c_{j,t}^{n,e}(a), k_{j+1,t+1}^{n,e}(a), c_{j,t}^{m,e}, k_{j+1,t+1}^{m,e}\}$ such that;

1. The consumption and saving choices $\{c_{j,t}^{n,e}(a), k_{j+1,t+1}^{n,e}(a), c_{j,t}^{m,e}, k_{j+1,t+1}^{m,e}\}$ solve the individual's utility maximization problem subject to budget constraints (3.2a-3.2c), (3.3a-3.3b), (3.4a-3.4b), (3.5a-3.5b).
2. The threshold ability $\{a_t^*\}$ satisfies the indifference condition in equation (3.6)
3. Prices $\{w_t^c, w_t^h, r_t\}$ satisfy the first order conditions of the firm's profit maximization problem stated in (3.12)
4. Aggregate physical capital and human capital by unskilled and skilled labor in efficiency units are consistent with individual behaviors as stated in equations (3.13), (3.14) and (3.15)
5. Government's budget constraint in equation (3.17) is satisfied.
6. Goods market clears.

$$C_t + I_t + \mathfrak{T}_t + G_t = Y_t$$

where

$$\begin{aligned} C_t \quad = \quad & \sum_{j=1}^{J} N_{j,t} \int_{a_{t-j+1}^*}^{\infty} c_{j,t}^{n,c}(a) f(a) da + \sum_{j=1}^{J} N_{j,t} \int_{0}^{a_{t-j+1}^*} c_{j,t}^{n,h}(a) f(a) da + \\ & \sum_{j=23}^{J} M_{j,t}^{c} c_{j,t}^{m,c} + \sum_{j=23}^{J} M_{j,t}^{h} c_{j,t}^{m,h} \end{aligned}$$

$$\mathfrak{T}_t = \sum_{j=1}^{4} N_{j,t} [1 - F(a_{t-j+1}^*)] T_t$$

3.3.6 Steady State

The model presented above is representative of the Canadian economy in which there are constant inflows of immigrants. The steady state can be characterized by the case in which the share of the foreign born population remains constant with continued inflows of immigrants to the economy i.e.,

$$\frac{M_{t+1}}{P_{t+1}} = \frac{M_t}{P_t} = \varkappa \tag{3.19}$$

This equality implies a constant growth rate of the population. Using (3.7), the growth rate of the population is given by;

$$\frac{P_{t+1}}{P_t} = 1 + \frac{I_{t+1}}{P_t} = 1 + g$$

The relation between g and $\varkappa$ is the following;

$$g = \frac{m_{_J}}{1 - \varkappa} \tag{3.20}$$

where $m_{_J} = \frac{M_{J,t}}{P_t}\ \forall t$. A stationary demographic structure requires that the age shares are constant i.e., $m_{j,t} = m_{j,t+1}\ \forall t$. Using this condition and the age shares defined for immigrants and natives in equations (**??**) and (3.9a), I get the following;

$$\begin{aligned} m_{23} &= \frac{g}{(1+g)},\ m_{j+1} = \frac{m_j}{(1+g)} \forall j = 23, ...J-1 \\ m_{_J} &= \frac{g}{(1+g)^{J-22}} \end{aligned} \tag{3.21}$$

Inserting m_J in equation (3.20), the growth rate of the population is found as;

$$g = \left(\frac{1}{1-\varkappa}\right)^{(1/(J-22))} - 1 \tag{3.22}$$

The share of native age groups are;

$$\begin{aligned} n_1 &= \frac{n_J + m_J}{(1+g)},\ n_{j+1} = \frac{n_j}{(1+g)} \forall j = 1, ...J-1 \\ n_{_J} &= \frac{m_J}{((1+g)^J - 1)} \end{aligned} \tag{3.23}$$

A stationary equilibrium is characterized by the system of equations where all variables are expressed in per capita terms and the growth rate of the population is as defined in equation (3.22).

3.4 MODEL PARAMETERS

The initial steady state of the model economy is calibrated to match some data moments of the Canadian economy at the beginning of the 1980's. The 1981 Survey of Consumer Finances Microdata set is used to calculate the data moments at the initial steady state unless otherwise stated. Model parameters can be classified into the following groups.

3.4.1 Production function parameters.

The share parameters $\{\mu,\ \lambda\}$ and the elasticity of substitution parameters $\{\theta,\ \rho\}$ are the production function parameters which need to be specified. I set $\rho = -0.495$ which is the value estimated by Krusell et al. (2000)[50] using the U.S. data. For θ, there is a range of estimates. Duffy, Papageorgiou and Perez-Sebastian (2004)[29] use a panel of countries and estimate θ to be around 0.8, while Krusell et al. (2000)'s estimate for this parameter is 0.401. Silos and Polgreen (2008)[70] estimate the same parameter to be 0.89. The value I pick for θ is 0.695 which is the average of these estimates. μ is calibrated to match the relative share of college graduates among natives. College graduates are 8.6% of the the native population in 1981 as reported in table 18. λ is chosen to match the income share of capital which is around 62% at the beginning of 1980's.[12]

3.4.2 Parameters of the ability distribution of natives

The ability distribution of natives is log normal with parameters m, v. i.e. $a \in F(a) \sim \log N(m, v)$. I normalize the mean of the ability distribution to 1 and calibrate the dispersion of the distribution to match the log difference between the hourly earnings of the native individual at the 90th percentile and the 10th percentile in 1981.[13] The log (P90/P10) value in the data is 1.32, meaning the individual at the top decile earns 132% more than the one at the bottom decile.

[12] Source: OECDStat, www.stats.oecd.org

[13] To compute this measure, I select the full-time full year wage and salary workers between ages 18 and 65.

3.4.3 Government Expenditure Parameters and Tax Rates

The condition for a balanced government budget is presented in equation (3.17). The government expenditures in in this equation is a constant fraction of output as follows:

$$G_t = \xi Y_t$$

The parameter ξ is set to the average share of government expenditures in Canadian total output between 1980 and 1990.[14] The other component of the government budget is social security benefits. I refer to Gruber (1999)[36] to calibrate the replacement rate (ψ) i.e., the fraction of average income which is paid out to an individual upon his retirement.[15] Gruber (1999)[36] computes the expected net present discounted value of Social Security Wealth which includes future entitlements from the four main social security programs in Canada. Using the median earnings history of a synthetic cohort from 1973-1993 SCF data, he calculates the replacement rates for all ages between 55 and 70.[16] I set ψ to 0.375, which are the replacement rates reported for a single individual with asset income at the age of 65.

The revenue of government comes from taxes on labor τ_l, and capital income τ_k. McDaniel (2007)[57] computes the average tax rate on labor and capital income for 15 OECD countries for the 1950-2000 period. Based on her calculations for Canada, I set $\tau_k = 0.285$ and pick τ_l so that the government budget constraint in equation (3.17) is satisfied.

3.4.4 Parameters Related to Demographics

Equation (3.22) gives the long run population growth rate as a function of the share of immigrant stock $\varkappa$ in the total population. To pin down $\varkappa$, I select the sample of immigrants who are aged between 22 and 85 from SCF 1981 data and find the sum of their relative weight in the total population. With the value of $\varkappa$ specified, the age shares of natives and

[14] Source: OECDStat: "National Accounts at a Glance"

[15] Gruber (1997) provides a brief summary of Canada's public pension plans. The public pension plans for seniors can be categorized under two main groups. The first one is the Old Age Security Program which includes the Old Age Security Pension and Guaranteed Income Supplement. The other category is the Canada and Quebec Pension Plans.

[16] In the paper the social security wealth is calculated by projecting all benefits out until the age of 100 and then taking a weighted sum which discounts future benefits by both the individual discount rate and the prospects that the worker will live to a given future age. The results are presented in tables 1-6.

immigrants can be calculated as a function of the population growth rate using equations (3.21) and (3.23).

3.4.5 Parameters Related to Immigration

Average ability level: The model exempts from an ability distribution for immigrants. All the college-educated immigrants are assigned an average ability level of $\overline{a}_m^c$ and the ones with less than a college education have an average ability level of $\overline{a}_m^h$. These average ability levels are calibrated to match the average wage gap between natives and immigrants of the same education level. The model implied average wage of college-graduate and less than college-educated natives and immigrants are given by the following equations;

$$\begin{aligned}
\overline{w}^{n,c} &= w^c . \int_{a^*}^{\infty} a f(a) \frac{1}{1 - F(a^*)} da_i \\
\overline{w}^{n,h} &= w^h . \int_{0}^{a^*} a f(a) \frac{1}{F(a^*)} da \\
\overline{w}^{m,c} &= w^c . \overline{a}_m^c \\
\overline{w}^{m,h} &= w^h . \overline{a}_m^h
\end{aligned}$$

so the log wage gap between college-graduate natives and immigrants is;

$$\ln(\frac{\overline{w}^{n,c}}{\overline{w}^{m,c}}) = \ln \left(\frac{\int_{a^*}^{\infty} a_i f(a_i) \frac{1}{1-F(a^*)} da}{\overline{a}_m^c} \right)$$

similarly the log wage gap between less than college-educated natives and immigrants is;

$$\ln(\frac{\overline{w}^{n,h}}{\overline{w}^{m,h}}) = \ln \left(\frac{\int_{0}^{a^*} a f(a) \frac{1}{F(a^*)} da}{\overline{a}_m^h} \right)$$

The log wage gap between college-educated and less than college-educated natives and immigrants is found by regressing log hourly wages on age, age squared, a dummy variable for males and a dummy variable indicating whether the individual is a native. Table 14 presents the results of these regressions for the college-educated and the less than college-educated respectively.

Education group	Log wage ratio
College graduates	0.034
Less than college graduates	0.029

Table 14: Wage gap between natives and immigrants

The initial assets of immigrants: Immigrants are assumed to arrive with a certain amount of savings in the model. Considering the current regulations for immigration in Canada, this is a reasonable assumption. Citizenship and Immigration to Canada (CIC) lists "having enough money to support yourself and your dependents after you arrive in Canada" as one of the criteria to be admitted as a skilled worker and professional immigrant.[17] The minimum amount required by CIC during the initial settlement period is set as $9,420 for a single individual by (CIC).[18] According to a research paper by Statistics of Canada based on the Longitudinal Survey of Immigrants 2001, three quarters of immigrants brought savings to the country upon their arrival. The median amount of savings by federal skilled workers is reported as $15,000 in the paper.[19] I assume that the median amount of savings did not change significantly from 1981 to 2001. This assumption allows me to find the median amount of savings by immigrants in 1981 as $7,600 in 1981 dollars. I calibrate the immigrants' initial assets as a fraction η of the average labor earnings the immigrant individuals. The median amount of savings is nearly 38.7% of the average wage income of FTFY foreign born workers in 1981 therefore I set $\eta = 0.387$.

3.4.6 Tuition Costs

Information on average undergraduate fees is available through Statistics Canada, Centre for Education Statistics. TLAC (tuition and living accommodation) data, available through the Centre, provides weighted average tuition fees for full-time Canadian undergraduate

[17] http://www.cic.gc.ca, Immigrating to Canada.

[18] "Skilled Worker Class: Will you qualify? : Proof of funds", CIC (2004) quoted from *"Asset-Based Approaches to Settlement Services in Canada" Jennifer Robson-Haddow and Sam Ladner*

[19] Longitudinal Survey of Immigrants to Canada A Portrait of Early Settlement Experiences, Statistics Canada. Catalogue no. 89-614-XIE

students. To calibrate the tuition costs in the model, I compute the ratio of the average tuition costs to the annual average wage earnings of individuals of age 18 who opt not to enroll in college and start working for wages. The ratio of the average undergraduate tuition fees to the average annual wage earnings of 18 year old FTFY wage and salary workers in the data is calculated as 9.02%. Hence I set the tuition parameter κ to 0.0902.

3.4.7 Other Parameters

The remaining parameters are the discount factor β, the CRRA parameter σ, the depreciation rate for physical capital δ, and the initial relative price of capital equipment $1/q_o$. The discount factor β is calibrated to match an average annual interest rate of 4%. I set the CRRA parameter σ to 1.5, which is a common value in the literature. I borrow the depreciation rate of capital from Li, Rao and Tang (2010)[54]. They report the depreciation rate used by Statistics Canada for aggregate physical capital as 0.16. Lastly the relative price of capital equipment in 1981, $1/q_o$, is normalized to 1.

3.5 CALIBRATION AND STEADY STATE RESULTS

In this section, I report the calibration results of the model and assess the model's performance in explaining some macro variables of the Canadian economy at the beginning of the 1980's. Table 15 summarizes the model parameters borrowed from outside sources and table 16 presents the calibrated parameters along with the targeted data moments. The results in table 16 suggest that the model does well in matching the data moments. The share of college-educated natives constitutes 8.62% of the native population. The model predicts the same ratio to be 9%. The variance of log normal ability distribution is calibrated as 0.45, which matches the overall income inequality measured by log (P90/P10) ratio. According to 1981 SCF data, the 90th percentile earns 132% more than the 10th percentile in hourly wages. In the model the log (P90/P10) ratio is 1.28 meaning 128% differential between the hourly wage earnings of the 90th and 10th percentile.

Table 17 reports some data moments which are not matched by construction. These

Parameter	Source
m =-0.101	Normalization
θ =0.695	Mean value of estimates
ρ =-0.495	Krusell et al. (2000)
τ_k =28.5%	McDaniel (2007)
ξ =0.22	OECDStat
ψ =0.375	Gruber (1999)
$\varkappa$ =20%	SCF 1981
J^* =48(age 65)	Gruber (1999)
$\varkappa_c$ =12%	SCF 1981
κ =9.02%	TLAC (1981)
δ =0.16	Tang, Rao and Li (2010)
σ =1.5	Common Value
η =0.387	StatCan

Table 15: Model parameters from outside sources

Parameter	Moment	Data	Model
$\mu = 0.56$	Share of college graduates among natives	8.60%	9.00%
$\lambda = 0.897$	Income share of capital	38.00%	38.00%
$\beta = 0.987$	Interest Rate (after tax)	4.00%	4.10%
$v = 0.45$	log P90/P10 ratio	1.32	1.28
$\overline{a}_m^c = 2.002$	Log wage gap-native and immigrants, college graduates	0.03	0.03
$\overline{a}_m^h = 0.867$	Log wage gap-native and immigrants, less than college	0.03	0.03
$g = 0.49\%$	The share of immigrant stock (age$\geq$ 22)	20.00%	20.00%

Table 16: Calibrated parameters and target moments

data moments are the wage bill ratio between college-graduate and less than college-graduate natives, capital output ratio, consumption output ratio, as well as some income inequality measures.

The model produces a wage bill ratio of 23% between college-educated and less than college-educated natives. The same ratio is 23.3% in the data. The average capital output ratio between 1972 and 1993 for the business sector in Canada is reported as 1.4 by Bentolila and Gilles (2003)[9]. The capital output ratio in the model economy is 1.75, which is close to its data value. Another important macro aggregate is the share of consumption in total output. Statistics Canada reports the 1981 share of consumption expenditures among total output as 52.8%. The initial steady state of the model produces a value of 43.4% capturing 82% of the share of consumption in the data.

The heterogeneity of individuals with respect to ability and education in the model provides the opportunity to study overall income inequality as well as inequality within education groups for the native population. Table 17 reports two non-targeted measures of overall income inequality, which are the log wage gap between the 90th and 50th percentiles and the 50th and 10th percentiles. The results for these two income inequality measures suggest that the model explains an important portion of the income inequality at the upper and lower tails of income distribution among natives. The model value for the log (P90/P50) ratio is 0.61 implying that, in the model, the native individuals at the top decile earns 61% more than the median. The same ratio in the data is 57%, so although the model predicts a higher upper tail income inequality than the one observed in the data, the difference is not significant. The 1981 data value of the difference between the log hourly wages of the median and the 10th percentile of the income distribution shows that the median individual earns 75% more than the individual in the first decile. The model predicts this ratio as 66% which explains 90% of the income inequality observed at the lower tail. In addition to these overall income inequality measures, college premium, which is the ratio of the average wage earnings of college graduates to less than college graduates is compared with its data counterpart. The model generates a college premium of 2.44 overpredicting its data value of 1.41.

Figure 2 shows the histogram of the ability distribution of natives. The ability distrib-

Variable	Model	Data
Wage bill ratio (natives)	23.00%	23.30%
Consumption output ratio	43.40%	52.80%
log(P50/P10)	0.66	0.75
log(P90/P50)	0.61	0.57
College premium (natives)	2.44	1.41
Capital output ratio	1.75	1.40

Table 17: Macro aggregates for the 1981 benchmark economy

ution is right skewed with a bulk of the ability levels being less than the mean ability level. The average ability levels of college-graduate and less than college-graduate immigrants are 2.002 and 0.87 as reported in table 16. This implies that the average ability level of immigrants with education below college is less than that of the average ability of the native population. The ability of college graduate immigrants is higher than the threshold ability level for college enrollment among natives. This means with immigration, individuals who can provide more human capital than some of the existing native workers are flow into the country.

3.6 COUNTERFACTUAL EXPERIMENTS

In this section, I present the results of some counterfactual experiments. These experiments aim to shed light on the long run impacts of exogenous changes in the foreign born labor force which took place between 1981 and 2008 in Canada.

Table 12 in the data section reports the increase in the immigrant population and the shift in their composition towards college graduates. Another change observed in the country between 1981 and 2008 is the fast decline in the price of machinery and equipment type of capital. Figure 3 illustrates the price of machinery and equipment relative to consumer non-

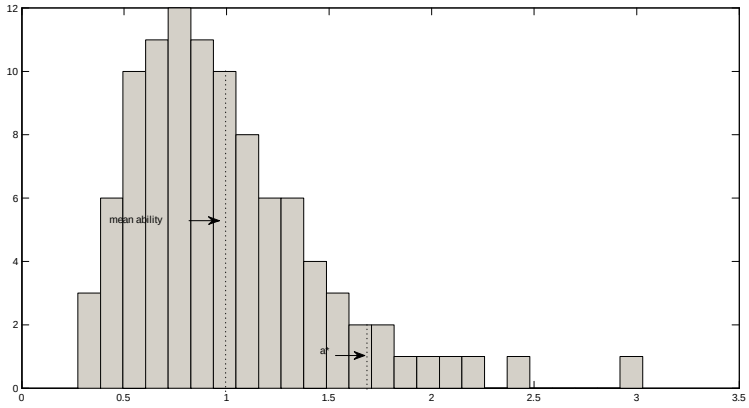

Figure 2: Histogram of ability distribution of natives. a*=1.67 is the threshold ability level for a college enrollment at the initial state. The mean of the ability distribution is normalized to 1.

durables in Canada. Between 1981 and 2008, the relative price of machinery and equipment fell by almost 50%. Based on Greenwood et al. (1997)[34], a decline in the relative price of machinery and equipment is identical to the case where the relative price of each vintage of capital is constant but its productivity is increasing over time. In a production environment where machinery and equipment is complementary to more educated or skilled labor, the period between 1981 and 2008 represents a period of increasing productivity for skilled labor.

Taken in a simple supply and demand framework, the stylized facts presented in table 12 and figure 3 suggest that the skilled labor market in Canada in the 1981-2008 period experienced a positive supply shock due to increasing inflows of college-educated immigrants and a positive demand shock stemming from declining relative price of machinery and equipment.

The first step of the counterfactual analysis is an assessment of the model's performance in explaining the economy in 2008. As mentioned above, I take into account three exogenous changes that took place between 1981 and 2008. These are the relative share of immigrants in the economy, the skill composition of the immigrants and the relative price of machinery and equipment. Panel A in table 18 compares the 1981 and 2008 values for these variables. In Panel B of table 18, I report the values for some key variables of the model and their

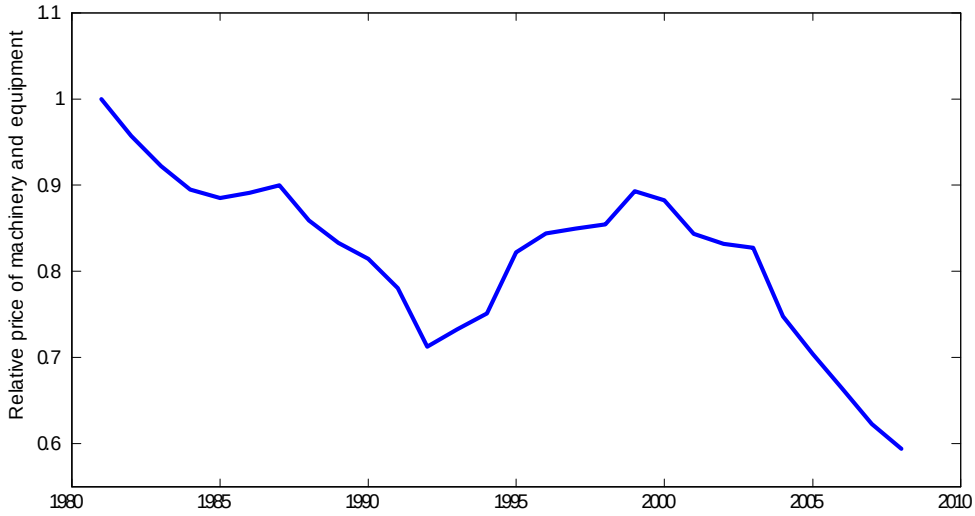

Figure 3: Price of machinery and equipment relative to consumer nondurables.The relative price in 1980 is normalized to 1. Source: *Author's calculation.*

data counterparts for the 2008 Canadian economy. From the beginning of the 1980's until the end of the 2000's, the college attainment rate increased among native Canadians. In 1981, the share of college graduates was 8.6%, which later soared to 24.4% in 2008. The model generates a similar increase in the college education attainment among natives. The predicted ratio of college graduates to non-college graduates for the 2008 economy is 25% in the model, which is very close to the 24.4% observed in the data. The model also explains an important portion of the increase in the wage inequality between the two main education groups. As reported in table 13, the increase in the ratio of average wage earnings of college educated to less than college educated natives is 8%. The model-predicted value for the percentage change in the college premium among natives is around 5.4%. With this prediction the model explains almost 70% of the increase earnings inequality between college graduates and those with less than college education. Overall, the model performs well in explaining the simultaneous increase in college premium and college attainment rate among natives between 1981 and 2008. The income share of capital displays a significant rise in the model from 38% to 52%. A similar upward movement is also observed in the data however

the magnitude is smaller - 2-3% points - in the data. The model captures the direction of the change in the wage bill ratio between college graduate and less than college-educated natives with some over prediction of its magnitude.

The overall income inequality measures used in this analysis are the log income difference between the top and bottom decile (log (P90/P10)), the top decile and median (log (P90/P50)) and the median and the bottom decile (log (P50/P10)). A comparison of the levels of the income inequality implied by the model and the 2008 data shows that the model captures an important portion of the inequality at the bottom end of the income distribution in 2008. The gap between the income of the median and the bottom decile is measured as 68% in the data, and the model predicts a 67% difference between median and bottom decile earnings. The values for the log (P90/P50) and log (P90/10) are higher than their data counterparts, meaning that the model generates a higher overall and upper tail income inequality. However the difference between the model's predictions and the data values are not pronounced.

How much did immigration contribute to the changes in the earnings and college attainment of native Canadians observed between 1981 and 2008? To answer this question, I simulate counterfactual 2008 economies, where I shut down the changes observed in the immigrant population. Recall that these changes are an increase in its share among the total population and a shift in its composition towards more college-graduate immigrants. Based on these observations, the first counterfactual experiment investigates how the increase in the relative share of college-educated immigrants among the total immigrant population affected the Canadian economy. The second experiment compares the counterfactual economy in which the immigrants maintain their 1981 share among the total population in the 2008 economy. The results of the counterfactual exercises are presented in table 19 and a discussion of the results is provided in the following subsections. The first subsection evaluates the impacts of immigration on the relative earnings of college graduates and the college decision of natives as well as the overall income inequality among the native population. The following subsection analyzes how the welfare of the native population changed due to an increase in the relative share of immigrants and their education level. In the last subsection I evaluate the same counterfactual scenarios in an environment where interest rates are fixed

at the benchmark 2008 economy level.

Panel A: Exogenous changes between 1981-2008

	1981	2008
Relative share of immigrants	20%	30%
Relative share of CG immigrants	12%	30%
Relative price of capital $(1/q)$	1	0.58

Panel B: 2008 economy Model vs. Data

	2008 economy	
Variable	Model	Data
CG native/total native	25.00%	24.40%
$\triangle$ College premium	5.40%	8.00%
log(P90/P10)	1.55	1.43
log(P50/P10)	0.67	0.68
log(P90/P50)	0.87	0.75
Income share of capital	52.00%	40.00%
Wage bill ratio (natives)	80.00%	65.00%

Table 18: Canadian economy in 1981 and 2008

3.6.1 College Education Decision and College Premium

The wage ratio of college-educated labor to less than college-educated labor provides a guideline to understand how immigration can affect the college decisions of natives and the college premium. Using the first order conditions derived from the firm's profit maximization decision, I get the following wage ratio;

$$\frac{w^c}{w^h} = \frac{(1-\lambda)(1-\mu)}{\mu}\{\lambda(qK)^\rho + (1-\lambda)(S)^\rho\}^{\frac{\theta-\rho}{\rho}}\frac{(S)^{\rho-1}}{(U)^{\theta-1}} \tag{3.24}$$

This wage ratio measures "the relative price of skill" in the economy. In other words, it is the wage earnings of a skilled worker relative to an unskilled one per efficiency units of labor he provides. The formula for the college premium among natives, which is comparable to the one observed in the data, depends on the relative price of skill as well as the ratio of the

average ability of college graduates and less than college graduates. Therefore the college premium is given by;

$$\text{College premium} = \frac{w^c . \int_{a^*}^{\infty} a f(a) \frac{1}{1-F(a^*)} da}{w^h . \int_{0}^{a^*} a f(a) \frac{1}{F(a^*)} da}$$

Krusell et al. (2000) compute the growth rate of the ratio of the wages for two types of labor as follows;

$$g_{\frac{w^c}{w^h}} \simeq (\theta - 1) g_{\frac{S}{U}} + (\theta - \rho) \lambda g_{\frac{qK}{S}} (\frac{qK}{S})^{\rho} \tag{3.25}$$

Here g_x denotes the growth rate of the variable x. The equation decomposes the change in relative price of skill into two parts. Using Krusell et al. (2000)[50] terminology the first effect is the *relative quantity effect,* which refers to the change in the share of skilled labor relative to unskilled labor. The second effect is the *capital skill complementarity effect,* which is mainly driven by the change in the efficiency units of capital per skilled labor.

The first counterfactual exercise investigates the impacts of a shift in the composition of the foreign born labor force towards college-graduate individuals between 1981 and 2008. The question I answer with this counterfactual exercise is as follows: If immigrants are still 30% of the total population in 2008, but the relative share of college graduates among the immigrant population remains at its 1981 value of 12%, what are the implications of this for the Canadian economy? Under this scenario, labor markets are loaded with more immigrants that are less than college-educated compared to the benchmark economy in 2008. The increase in the share of workers below college education results in a decline in their wages. In other words, the *relative quantity effect* works in the direction of increasing the relative price of skill. An increase in the share of unskilled immigrants also has implications for the physical capital stock for the economy. Immigrants with less than college education save less than their college-educated counterparts as illustrated in figure 15. This leads to a smaller physical capital stock in the economy which acts as a drag on the wage ratio. So the relative quantity and capital skill complementarity effects work in opposite directions on the wage ratio between skilled and unskilled labor. How does college attainment among natives respond to these changes? Under this counterfactual scenario, the share of native individuals who continue with a college education are 7% points higher. This implies, if the

composition of immigrants in Canada did not shift towards college graduates, 7 more natives out of every 100 would be willing to get a college education. However, the natives who opt for college education in the counterfactual economy have lower ability levels. Compared to the benchmark economy in 2008, the college-graduate labor force is composed of more natives with a lower average ability level. The resulting impact on the human capital provided by college graduates relative to non-college graduates is a decline. As a result of the relative scarcity of skilled labor, the relative skill price displays an increase from 1.22 to 1.24. One interesting result to point out is the decline in the average college premium among natives. In the counterfactual 2008 economy with less college-educated immigrants, the college premium increases by 4.9%. This is a 0.5% points less increase in the growth rate of the average college premium compared to the benchmark case. The main reason for the slower rise in the average earnings premium enjoyed by college graduates is the lower average ability level among college graduates. Although college-educated workers earn more per unit of human capital, their average earnings relative to high-school graduates is smaller under the counterfactual economy due to the decline in the average human capital they provide.

In the second exercise, I analyze the effects of having a higher share of immigrant population on native Canadians in 2008. To achieve this, I construct a counterfactual 2008 economy in which the relative share of immigrants is at its 1981 level. The results of this experiment are presented in column 5 of table 19. An immediate impact of having fewer immigrants in the economy is a decline in the labor supply by two education groups. This leads to an increase in the wage earnings of both college graduates and those with less than a college education. The model also predicts the per capita physical capital in the counterfactual economy with a smaller immigrant population to be higher. The main reason for the surge in the per capita capital is the decline in the population with less immigrants.

The wage earnings of skilled labor relative to unskilled labor is slightly lower in the economy with a smaller immigrant population. Recall that this wage ratio depends on the *relative quantity effect* and *capital-skill complementarity effect*. Under this scenario, the increase in capital per skilled labor pulls up the relative skill price. On the other hand, the relative quantity effect works in the opposite direction. In the counterfactual economy with fewer immigrants, the ratio of skilled labor to unskilled labor is higher. This is due

to more natives opting for a college education. A higher ratio of skilled labor to unskilled labor drags the relative skill price and offsets the capital-skill complementarity effect. The final resulting change in the wage ratio is a 1% decline.

Despite the fact that the relative skill price is slightly less, the interest rates are lower under the counterfactual economy. Interest rates decline as an outcome of the increase in the per capita physical capital. This makes the loans borrowed to cover tuition expenses more affordable for natives, and hence increases the net value of college education. The resulting change in the college decisions of natives is an increase by 3 % points compared to the benchmark 2008 economy. In other words, with fewer immigrants in the economy, 3 more natives out of 100 are willing to get a college education. The average college premium among natives also exhibits a slower growth rate under the economy with a smaller immigrant population. This stems from the lower relative skill price and the average ability of college-graduate natives compared to the benchmark economy.

An evaluation of the impacts of all changes observed in the immigrant population between 1981 and 2008 on the Canadian economy is reported in the last column of table 19. This counterfactual scenario illustrates the case in which the immigrant population does not change between 1981 and 2008. In accordance with the previous two counterfactual experiments, college attainment among natives is 7% points higher compared to the benchmark economy. This increase in college attainment is an outcome of the higher net value of being a college graduate as mentioned above. Comparing the relative wage earnings of skilled labor with the benchmark 2008 economy shows that the relative skill price is slightly lower. Although there is no significant change in the relative earnings per efficiency units of college-graduate labor, the average college premium enjoyed by natives exhibits a slower growth under the counterfactual economy due to the composition effects.

To sum up, the changes in the immigrant population observed between 1981 and 2008 in Canada have important effects on the college attainment of natives. The bulk of the decline in the college attainment of natives is due to the shift in the composition of immigrants towards college graduates. In other words, the selective immigration policy of Canada discourages natives with lower ability levels from pursuing a college education and replaces them with foreign born ones. The changes in the immigrant population also have impacts

on the average wage earnings of skilled workers relative to the unskilled ones. Both the increase in the share of immigrants and the shift in their composition increases the average premium paid to college-graduate natives. The model predicts that the contribution of immigration to the rise in college premium among natives between 1981 and 2008 is around 2.3% points. This is around 40% of the total increase predicted by the model.

The model provides an environment in which immigration can be evaluated in terms of the impacts it has on the measures of overall income inequality. A comparison of the benchmark economy in 2008 with the counterfactual economies shows that immigration has no significant impact on the overall income inequality as well as the income inequality at the lower and upper tails. The increase in the overall income inequality (P90/P10) as well as the upper tail (P90/P50) and lower tail (P50/P10) income inequality observed between 1981 and 2008 are due to improvements in technology which favor skilled labor. In their discussion of the increase in overall and upper tail income inequality observed in the U.S., Autor, Katz and Kearney (2008) refer to *compositional* and *price* effects. They argue that changes in the composition of the labor force with an increase in individuals with higher education or higher experience levels may result in increased income inequality. In their words

> "Changes in the distribution of education or experience can lead to changes in wage dispersion. These *compositional* effects are distinct from the standard price effects arising from shifts in supply-demand and institutional factors. Holding market prices constant, changes in labor force composition can mechanically raise or lower residual earnings dispersion simply by altering the employment share of worker groups that have more or less dispersed earnings. Similarly, changes in workforce composition can also raise or lower overall earnings dispersion by increasing or reducing heterogeneity in observed skills."

Based on their argument, the increase in the overall and the upper tail income inequality arises due to an increased heterogeneity in the composition of the labor force in an environment where advances in technology are favoring skilled labor.

Variable	Benchmark economy		2008 economy under counterfactual scenarios		
	1981	2008	No change in CG share among FB	No change in the size of FB	No change in FB population
w^c/w^h	1.05	1.22	1.24	1.20	1.21
Share of college graduates	9.00%	25.00%	32.00%	28.00%	32.00%
k/s (efficiency units)	8.57	15.22	15.16	15.47	15.41
s/u	0.24	0.74	0.71	0.80	0.78
k/y	1.75	2.08	2.05	2.14	2.12
$\triangle$ College premium	-	5.40%	4.90%	3.20%	3.08%
Interest rate	4.09%	6.36%	6.46%	6.10%	6.17%
w^c	0.62	0.97	0.97	0.98	0.98
w^h	0.59	0.79	0.78	0.81	0.80
Tax rate	56.80%	61.80%	62.50%	59.20%	59.70%
log(P90/P10)	1.28	1.55	1.55	1.53	1.53
log(P50/P10)	0.66	0.67	0.67	0.67	0.67
log(P90/P50)	0.61	0.87	0.87	0.85	0.85

Table 19: Counterfactual experiments: Column 4 is the 2008 economy in which the the relative share of college graduates among the immigrants is the same as in 1981. Column 5 represents the case in which the relative size of the foreign born labor force is kept at its 1981 level and column 6 reports the results for the case in which the foreign born population remains the same as in 1981.

3.6.2 Welfare Comparisons

Changes in the immigrant population affect all factor returns in the economy as presented in the previous section. In order to understand the overall impact of changes in all factor returns on the natives, I quantify the welfare impacts of immigration. The welfare comparisons are based on the Lucas' measure which can be expressed as follows[20];

$$\sum_{j=1}^{J}\beta^{j-1}u((1+\lambda)c_{o,j}(a)) = \sum_{j=1}^{J}\beta^{j-1}u(c_{1,j}(a)) \tag{3.26}$$

where $c_{o,j}(a)$ and $c_{1,j}(a)$ represent the consumption of a native of age j, and ability level a for the benchmark case in 2008 and the 2008 economy under counterfactual scenarios. In this formulation λ measures the percentage change in permanent consumption that the individual experiences due to the changes in immigrant population. Table 20 reports the values of λ for the highest, median and lowest ability individuals in the economy.

I begin the analysis by examining the welfare impacts of the shift in the composition of immigrants towards college graduates. I analyze this case by computing the percentage change in permanent consumption under the scenario that the share of college graduates among the foreign born does not change. In other words, this is the counterfactual 2008 economy in which immigrants are 30% of the total population but the relative share of college graduates among immigrants is at its 1981 level of 12%. The results in panel A show that all three types of natives experience a welfare loss under this scenario. This is an outcome of higher tax rates on labor earnings and lower wages of both education groups in the counterfactual economy. In this economy compared to the benchmark one there are more immigrants with education level below college. This results in a drop in the wages of median and low ability workers who opt out of college education. For the highest ability individual there is also a decrease in the labor earnings resulting from the higher college attainment rate among natives. The welfare loss of the highest ability individual amounts to 0.016% drop in his permanent consumption. The lowest and median ability individuals also suffer a loss in welfare equivalent to a drop of 0.023% in their permanent consumption

[20] Lucas measures the welfare cost of business cycles by calculating the λ which he defines to be the change in the permanent consumption of individuals.

levels.

Panel B reports the welfare effects of an increase in the relative share of the immigrant population. In the counterfactual 2008 economy where the relative share of immigrants is the same as its 1981 value, highest, lowest and median ability natives enjoy a 0.07% increase in permanent consumption. This result implies that an increase in the relative size of the immigrant population creates a welfare loss for these natives. The main reason for this loss is the decline in the wages of both skilled and unskilled labor. Although the interest rate is 0.3% points higher in the benchmark 2008 economy, the increase in capital income is not enough to compensate for the decline in labor earnings. Also a comparison of the tax rates shows that, the tax rate on labor income is higher under the benchmark 2008 economy than the counterfactual economy. This is another factor which contributes to the welfare loss accruing to natives due to the increase in the relative size of immigrants.

Finally I examine how the increase in the size of the immigrant population along with a shift in its composition towards college graduates change the welfare of natives. The results of this analysis are presented in panel C of the table. Under the counterfactual economy where the immigrant population is the same as in 1981, all three types of native enjoy a 0.06% points increase in their permanent consumption. Based on this result, I infer that the overall changes of the immigrant population created a loss for natives in Canada between 1981 and 2008. As mentioned above, these losses are an outcome of the decline in wages due to immigration and higher labor income tax rates. The results of the counterfactual experiments in panels A and B show that the welfare loss of natives resulting from changes in the immigrant population is mainly due to the increase in its size. On the other hand, admitting more college-graduate immigrants to the country benefits natives at the upper and lower ends of the ability distribution as well as the median individual.

Borjas (1994)[11] is one of the first studies which examines the welfare impacts of immigration. He calculates the increase in the income accruing to natives due to immigration, i.e., an "immigration surplus". In his partial equilibrium setting, an immigration surplus occurs because, although there is a reduction in the wages of natives, the rise in interest rates results in an increase in capital income. This soar in capital income more than compensates for the reduction in the labor earnings of natives which in the end creates net positive gain

of immigration to the native population. He reports the increase in the income accruing to the native population due to a 10% increase in the labor force due to immigration to be on the order of 0.1 % of GDP, assuming that labor and capital are not perfectly substitutable. However, the immigration surplus becomes even smaller with endogenous physical capital.[21] Individuals adjust their saving decisions in response to an immediate rise in the interest rates which increases the physical capital stock in the economy. This in turn drives down the increase in capital income accruing to the native population. The results in table 19 show that in the benchmark 2008 economy, the interest rates are higher compared to the counterfactual economy with no changes in the immigrant population. However the decline in the wages for both education groups combined with higher labor income taxes outdoes the increase in interest rates. This creates the decrease in the permanent consumption of all three ability levels in my model.

How do the welfare impacts of immigration compare to the other general equilibrium models which take the human capital of natives as exogenous? An important result presented in table 19 is that the selective immigration policy of Canada, which encourages college graduates, results in a reduction in the share of college graduate natives. As discussed above, all three ability types of natives experience a nearly 0.02% decrease in their permanent consumption if the skill composition of immigrant population does not change. The reason for median and low ability individuals to suffer a decline in their permanent consumption is that in this economy there are more immigrants with an education below the college level in the country which results in a reduction in unskilled wages compared to the benchmark 2008 economy. For the college graduates, the decrease in permanent consumption is an outcome of the endogenous college education decision. Despite the fact that there is a smaller share of college graduate immigrants in the economy compared to the benchmark case, the higher college attainment rate among natives prevents a possible increase of college graduate wages in the economy. That is the main reason for not observing a higher increase in the welfare of the highest ability individual under the 2008 economy where the skill composition of the immigrant population is the same as in 1981.

Ben-Gad (2008)[8] runs a similar experiment for the U.S. economy whose results can be

[21] Ben-Gad (2004,2008) point to this fact.

compared qualitatively to the counterfactual scenario in panel A. He analyzes the percentage change in permanent consumption for skilled and unskilled households due to an increase in the unskilled immigration rate. In that case, skilled households enjoy an increase in their welfare whereas unskilled households face a drop in their permanent consumption levels. The reason for the increase in the permanent consumption of skilled households in his model is that with more unskilled immigrants in the economy, the skilled labor force becomes less scarce. This increases their wage earnings hence their welfare. In other words, in the absence of an endogenous human capital channel, the native population's response of increasing their educational attainment to spur an increase in skilled wages is not taken into account. This makes a surge in unskilled immigration beneficial for skilled households. A similar increase in the welfare of the highest ability individual is not observed in the current model because the higher college attainment among natives drives down their wages, hence their welfare.

% change in the permanent consumption of natives	
A. No change in college graduate share among immigrants	
Highest ability	-0.016
Median ability	-0.023
Lowest ability	-0.023
B. No change in the relative size of immigrants	
Highest ability	0.071
Median ability	0.074
Lowest ability	0.074
C. No change in immigrant population	
Highest ability	0.059
Median ability	0.058
Lowest ability	0.058

Table 20: Welfare analysis of immigration

3.6.3 Partial Equilibrium Analysis

In the general equilibrium setting the factor returns, i.e. wage and interest rates are determined endogenously in equilibrium. They adjust to changes in the individual's human and physical capital accumulation choices. In this section, I analyze how the changes in the immigrant population would affect the Canadian economy if the interest rates were fixed at a certain level.

A fixed interest rate in the economy changes the total physical capital stock by affecting the savings choice of individuals. The impact of the change in the physical capital stock is realized through two channels. The first is the wage earnings channel. Physical capital is an input to the production process together with the skilled and unskilled labor. A higher level of capital results in higher productivity, therefore higher wages, for both types of labor. In a production setting where physical capital is more complementary to skilled labor the wages of skilled workers respond more to the changes in the physical capital stock.

Changes in the physical capital stock in the economy also have implications for the equilibrium tax rate in the model economy. Both taxable labor and capital income depend on the physical capital stock. An increase in the physical capital stock results in higher wages, therefore a higher labor income. On the other hand, the capital income also increases in response to a higher level of physical capital in the economy. The direction and magnitude of the change in equilibrium tax rate depends on the interaction between labor and capital income in this case.

Natives' college education choices are naturally affected from all these changes in wages and equilibrium labor income tax rate. A native individual decides whether or not to get college education by comparing the benefits and costs of college education. In other words, the share of college-educated individuals among the native population depends on;

i) The wage difference between college graduates and high school graduates less of taxes

ii) The opportunity cost of college education which corresponds to the foregone wage earnings less of taxes during college education years

iii) The direct cost of schooling in other words the total amount of tuition loans individuals get to finance their college education

As the differential between the wages earned by a college-educated and high school-educated individual per efficiency unit of labor provided widens, the incentive to enroll in college increases. On the other hand, a higher level of wages earned by high school graduates has an opposite impact on the college education incentives of natives because it implies a larger opportunity cost of college education. An increase in labor income tax has two opposing effects. Firstly higher tax on labor income will decrease the net level of earnings gap between college graduates and high school graduates, ceteris paribus. In addition, by decreasing the net income gained by unskilled workers, it will result in a lower opportunity cost of schooling. Changes in interest rates also affect the individual's college education choice by increasing or decreasing the burden of the loans individuals borrow to finance their education.

Table 21 reports the results of the counterfactual experiments in a partial equilibrium setting where the interest rates are kept constant at the 2008 benchmark economy levels. The partial equilibrium results give an idea about the small open economy version of the model where the country takes the interest rate as given.

When the interest rates are fixed at 6.36% a smaller share of natives go to college in the counterfactual economy with no change in the skill composition of immigrants. In the partial equilibrium model the interest rates and wage earnings of high school graduates are lower resulting in a lower direct and opportunity cost of college education. These channels work in the same direction and increase the incentives to get college education. Compared to the general equilibrium case, the wage gap between college and high school graduates and labor income tax rates are higher in the partial equilibrium model. An individual benefits from more premium by opting for college education in an economy with lower interest rates, however the higher income taxes drag down the differential wage earnings. The reason for observing a slightly lower ratio of college graduates among natives is the higher labor income taxes which reduce the motivation to get college education in comparison to the general equilibrium setting where taxes on labor income are lower.

Column 5 in table 21 presents the results for the counterfactual 2008 economy with no change in the relative size of immigrants. The college graduates make up a 1% higher share of the total native population. In this economy the interest rates are 0.26% points more

compared to the general equilibrium case. Facing higher fixed interest rates individuals save more which increases the total physical capital stock in the economy. The larger stock of physical capital boosts the productivity hence the wages of both skilled and unskilled labor. Skilled workers benefit more from the accumulation of capital in the economy since physical capital is more complementary to the labor services provided by the college-educated. The bigger increase in skilled wages leads to a higher premium for college education thereby motivating more natives to enroll in college compared to the general equilibrium case. On the other hand higher interest rates and unskilled wages pull up the cost of college education which work in the opposite direction and diminish the net benefit from enrolling in college. The observed increase in the share of college-educated natives shows that the increase in college premium effect dominates the higher cost of college education therefore more natives opt for college education.

In the counterfactual economy with no change in the immigrant population and fixed interest rates, the relative share of natives who go to college are 18% points higher than the same economy with variable interest rates. With fixed and higher interest rates the premium from getting college education is more and the labor income tax rates are lower. These two changes together generate a greater net gain of enrolling in college than the general equilibrium case with variable interest rates. Meanwhile both the direct and the opportunity cost of college education in terms of foregone wage earnings are higher in the partial equilibrium model. The observed increase in the relative share of college-educated natives implies that the rise in the net earnings gain from college education more than offsets the negative impacts of higher costs of college education on the college education incentives of individuals.

Variable	2008 economy under counterfactual scenarios					
	No change in CG share among FB		No change in the size of FB		No change in FB population	
	General Equilibrium	Partial Equilibrium	General Equilibrium	Partial Equilibrium	General Equilibrium	Partial Equilibrium
w^c/w^h	1.24	1.25	1.20	1.25	1.21	1.23
Share of college graduates	32.00%	30.00%	28.00%	29.00%	32.00%	50.00%
k/s (efficiency units)	15.16	15.08	15.47	16.39	15.41	19.96
s/u	0.71	0.66	0.80	0.83	0.78	1.48
k/y	2.05	2.01	2.14	2.22	2.12	2.71
$\triangle$ College premium	4.90%	6.15%	3.20%	6.15%	3.08%	3.7%
Interest rate	6.46%	6.36%	6.10%	6.36%	6.17%	6.36%
w^c	0.97	0.97	0.98	1.03	0.98	1.21
w^h	0.78	0.77	0.81	0.82	0.80	0.98
Tax rate	62.50%	63.00%	59.20%	60.03%	59.70%	47.26%

Table 21: Counterfactual experiments: Partial vs. general equilibrium results. Partial equilibrium results are achieved by fixing the interest rate to its level in benchmark 2008 economy

3.7 CONCLUSION

The immigrant population in Canada went through remarkable changes between 1981 and 2008. In addition to the significant increase in their relative share among the total population, the country's selective immigration policy attracted many highly educated workers to the country. This paper evaluates how the changes in immigrant population between 1981 and 2008 affected native Canadians. In particular, I quantify the impacts of immigration on the college attainment and the welfare of natives as well as the wage inequality between college graduates and non-college graduates. My findings suggest that the immigration experience of Canada resulted in lower college attainment rates among natives between 1981 and 2008. The results from counterfactual experiments show that the share of college graduates among natives decreases by 7% points due to changes in the immigrant population. The counterfactual experiments which isolate the impact of the increase in the relative share of immigrants and the shift in their composition reveal that the main factor which discourages natives from college education is the increase in the relative share of college graduates among immigrants.

A larger immigrant population with more college graduates increases the college premium among natives slightly. The main reason for the increase in the college premium is that higher ability natives are selected into college education in response to having more and higher educated immigrants. This results in an increase in the average ability of college-graduate natives relative to those with education below college, hence increasing the average wage earnings ratio between to college and high school graduates.

The welfare analysis shows that natives at both ends as well as the middle of the ability distribution enjoy higher welfare in the economy where college graduates are a higher proportion of the immigrant labor force. This result is interesting because it suggests that even the highest ability native who is a college graduate benefits from the selective immigration policy of the country. The main reason for the increase in welfare is the increase in the labor earnings of both education groups as well as the lower tax rate in the economy. On the other hand, the increase in the relative size of immigrants decreases the permanent consumption of natives of all ability levels by nearly 0.1%. Unlike the shift in the composition

of immigrants towards college graduates, the increase in the relative share of the immigrant population results in lower wages and higher labor income tax rate for both education groups. The combined impact of lower wages and higher labor income taxes is a decrease in permanent consumption which decreases the welfare of natives. Overall, the results of the welfare analysis suggest that the selective immigration policy of Canada benefits both college-graduate and less than college-graduate natives who are at the lower and upper ends as well as the middle of the ability distribution. On the other hand, an increase in the size of the immigrant population creates a welfare loss for these natives.

4.0 UNDOCUMENTED WORKERS' EMPLOYMENT OVER THE U.S. BUSINESS CYCLES

4.1 INTRODUCTION

The objective of this paper is to analyze the differences in the variation of undocumented and documented workers' employment during the business cycles in the U.S. between 1990 and 2008. The changes in the adjustment of employment of undocumented worker during economic booms and recessions could have important policy implications. The employment of undocumented workers might be seen as a buffer in the labor market. In other words, undocumented workers might represent a cushion or latent group of workers which provide employers hiring and firing flexibility across variations in product demand. If this is the case, immigration reform that restricts the number, or affects the status, of undocumented workers might also curtail the flexibility in labor markets that employers currently have, increasing their hiring costs along with the likelihood of an increase in consumer prices. The degree to which differences in employment variability between documented and undocumented workers can be quantified will provide a better understanding of the impact on employers of restricting access to a source of flexible labor might be.

According to our review, there are no studies on undocumented immigration employment over the business cycles. However, if we consider that more than 62% of undocumented workers come from Mexico and 47% of unauthorized workers between 25-64 years old have less than high school education, we can draw some suggestions from specific studies on the adjustment of low-skilled and immigrant workers relative to higher-skilled and native workers over economic fluctuations.

Castro and Coen-Pirani (2008)[23] study the cyclical behavior of hours worked by skilled

labor in the U.S. between 1979 and 2003. They document that skilled hours have become more volatile since 1984. Using a production function with complementarity between capital and skilled labor they show that they can explain 60% of the increase in the volatility of skilled hours.

Hoynes (2000)[45] examines the relative impact of economic cycles on the employment, earnings, and income of individuals across different skill groups. Her findings show that the labor market outcomes of less-skilled workers exhibit more variability over business cycles than those of higher-skilled groups. She also concludes that non-whites and those with lower education levels are more impacted by changes in economic conditions.

Using Census data, Orrenius and Zavodny (2010)[62] analyze the impact of recessions on Mexican immigrants. Their results indicate that low-educated Mexican immigrants' employment and unemployment are more responsive to business cycle fluctuations than are Hispanic and white non-Hispanic US natives. In addition Dustmann, Glitz and Vogel (2010)[30] study the differences in the cyclical pattern of employment and wages of immigrants and natives for Germany and United Kingdom. They find significantly larger responses to economic shocks for immigrants relative to natives within the same skill group, and for low-skilled workers relative to high-skilled workers. Further evidence of the dramatic cyclical variability of employment among immigrants is found in Mandelman and Zlate (2010)[56]. They track a great deal of cyclical variability in remittances originating in the U.S. Variations in employment outcomes will necessarily impact the availability of funds to send home.

From these previous studies, it might be expected that undocumented workers are more exposed to business cycle fluctuations than documented workers. Due to their lower skill levels, including the high probability of not being able to speak English well, employers are likely to first dismiss undocumented workers during an economic downturn, as they attempt to preserve productivity levels while cutting costs. In addition, employers informally hiring undocumented workers would likely face lower fixed costs of hiring and dismissing undocumented workers. Further, employment of undocumented workers is concentrated in certain industries and occupations that might be more sensitive to economic fluctuations.

On the other hand, there could be countervailing factors affecting cyclical variation in undocumented workers' employment. For example, Pena (2010)[67] shows evidence that

undocumented workers are typically paid lower wages than similarly skilled documented workers. Hotchkiss and Quispe-Agnoli (2010)[44] explain the wage differential by differences in productivity. Brown, Hotchkiss and Quispe-Agnoli (2008)[16] find that firms who hire undocumented workers enjoy a competitive advantage. These factors would perhaps result in undocumented workers being the last to be dismissed during an economic downturn, as dismissing documented workers would reduce costs by a greater amount. In addition, Borjas (2001)[12] points out that undocumented workers like immigrants in general, are typically more mobile geographically and across industries and occupations than native workers. This suggests that undocumented worker employment may not suffer as greatly as documented workers employment during economic downturns, as undocumented workers are more flexible in chasing the remaining jobs. Orrenius and Zavodny (2010)[62] draw attention to previous research's findings that immigrants' vulnerabilities tend to outweigh these positive factors. Based on this they conclude that immigrants' employment and earnings of immigrants are more sensitive to business cycle fluctuations than that of natives.

Undocumented workers' employment could appear to be more sensitive to business cycle fluctuations if undocumented workers experience higher levels of separation overall. Hotchkiss and Quispe-Agnoli (2010)[44] find that during the expansionary period of 1997-2000, the average quarterly separation rate for documented workers was 18.4% and for undocumented workers 40%. On average, undocumented workers are likely to have been on their current job a shorter amount of time, have less labor market experience, and reflect greater separation behavior (not holding anything else constant). In addition, Morales (1983)[58] provides evidence that undocumented workers appear to be concentrated among smaller employers who experience a greater degree of churning among its workforce, suggesting a need for workforce flexibility in its production process.

In our study, we examine the employment of undocumented and documented workers at business cycle frequency looking at quarterly data for the state of Georgia between 1990 and 2008. The analysis of the business cycle properties of the undocumented employment reveals that undocumented workers' employment is more volatile during business cycles compared to documented ones. Another observation is that the volatility of documented employment remains constant throughout the whole period whereas a decline in the volatility

of undocumented employment is observable after 1999. For the purposes of this study we focus on the higher volatility of the undocumented employment and provide an explanation for this data fact.

Our hypothesis for explaining larger adjustments in employment outcomes among undocumented workers than documented workers across the business cycle is the higher elasticity of substitution of undocumented labor with physical capital compared to documented labor. This explanation is inspired by numerous other studies that examine the elasticity of substitution between capital and different types of labor. In these studies, focus is mostly on different education groups of workers. Griliches (1969)[35] was the first to document the complementarity between skilled labor and physical capital. Berndt and Christensen (1974)[10], Fallon and Layard (1975)[32], Denny and Fuss (1977)[27], Brown and Christensen (1981)[17] also report evidence that the unskilled labor is more substitutable with capital than skilled labor. A more recent study by Krusell, Ohanian, Rios-Rull and Violante (2000)[50] (hereafter KORV (2000)) estimate the elasticity of substitution between unskilled labor, skilled labor and capital equipment. They use a CES production technology with two types of capital and find that skilled labor is complementary to capital. Their estimate for the elasticity of substitution between unskilled labor and capital suggests a higher degree of substitutability between these two factors than the Cobb-Douglas case.

Based on the above mentioned empirical evidence, our strategy is to replace undocumented labor with the unskilled and documented labor with skilled and use the same production technology as in KORV (2000)[50] with one type of capital. The intuition for the link between the volatility of undocumented labor and its elasticity of substitution with capital is as follows: If capital is fixed in the short-run and undocumented workers are more substitutable with capital than documented workers, firms will make short-run adjustments to production levels in response to economic variation in product demand by adjusting employment levels of undocumented workers. This will make the employment of this group more volatile compared to the documented ones.

The results from our quantitative analysis suggest that with a production technology where undocumented workers are more substitutable with capital than documented labor, we can explain the higher sensitivity of undocumented employment to business cycles. The

model does particularly well in matching the volatility of the undocumented employment for the 2000-2008 period explaining almost 80% of the variation of the employment of this group at business cycle frequency.

The paper is organized as follows. Section 4.2 discusses the data and section 4.3 presents the stylized data facts. In section 4.4, we explain our theoretical framework and our quantitative analysis, finally section 4.5 concludes.

4.2 DATA

The primary data used for the analyses in this paper are the Employer File and the Individual Wage File compiled by the Georgia Department of Labor for the purposes of administering the state's Unemployment Insurance (UI) program. These data are highly confidential and strictly limited in their distribution. The data are available from the first quarter of 1990 through the fourth quarter of 2008. The Employer File provides an almost complete census of firms, covering approximately 99.7% of all wage and salary workers.[1] The establishment-level information includes the number of employees, the total wage bill, and the NAICS classification of each establishment. The Individual Wage File links individual workers to their employer. The data also contain a 6-digit NAICS industry code and the county of location, allowing us to construct or merge in industry and county level indicators, such as county unemployment rate.[2]

4.2.1 Identifying Invalid Social Security Numbers

Every quarter employers must file a report with their state's Department of Labor detailing all wages paid to workers who are covered under the Social Security Act of 1935.[3] Each worker on this report is identified by his/her social security number (SSN). There are a number of ways in which one can establish that a reported social security number is invalid. The Social Security Administration provides a service by which an employer can upload

[1] Source: *Committee on Ways and Means (2004)*

[2] Regrettably, the data set contains no information about workers' demographics or immigration status.

[3] For information about which workers are covered, see U.S. Department of Labor (2008).

a file of SSNs for checking, but one must register as an employer to obtain this service.[4] In addition, there are several known limitations on what can be considered a valid social security number, so a simple algorithm is used to check whether each number conforms to the valid parameters.

There are three pieces to a SSN.[5] The first three numbers are referred to as the area number. This number is assigned based on the state in which the application for a SSN was made; it does not necessarily reflect the state of residence. The lowest area number possible is 001 and the highest area number ever issued as of December 2008 is 772. Using information provided by the SSA, the dates at which area numbers between 691 and 772 are first assigned can be determined. Any SSN with an area number equal to 000, greater than 772 or which shows up before the officially assigned date will be considered invalid. The last four digits of a SSN are referred to as the serial number. These are assigned consecutively from 0001 to 9999. Any SSN with a serial number equal to 0000 is invalid.

In 1996 the Internal Revenue Service (IRS) introduced the Individual Tax Identification Number (ITIN) to allow individuals who had income from the U.S. to file a tax return. It is simply a tax processing number and does not authorize an individual to work in the U.S. Employers are instructed by the IRS to not accept an ITIN in place of a SSN for employee identification for work. An ITIN is only available to resident and nonresident aliens who are not eligible for U.S. employment and need identification for other tax purposes.[6] ITIN numbers have a "9" in the first digit of the area number and a "7" or "8" in the first digit of the group number. Anyone with this numbering scheme will be identified as having an invalid area number. The percent of SSNs with high area numbers that also match the ITIN numbering scheme has risen from about one percent in 1997 to over 60% by the end of 2006.

A series of SSNs were de-commissioned by the Social Security Administration because they had been put on fake Social Security Cards used as props to sell wallets.[7] Apparently, some people who purchased the wallets thought the fake Social Security Cards were real and

[4] See Social Security Number Verification Service <http://www.ssa.gov/employer/ssnv.htm>.

[5] Historical information and information about valid SSNs can be found at the Social Security Administration's web sites: <http://www.ssa.gov>, <http://www.socialsecurity.gov>

[6] "Hiring Employees" <http://www.irs.gov/businesses/small/article/0,,id=98164,00.html> Also see "Individual Taxpayer Identification Number" <http://www.irs.gov/individuals/article/0,,id=96287,00.html>.

[7] See U.S. Department of Housing and Urban Development (1990).

started using them as their own. If any of these 21 "pocketbook" SSNs appear in the data, they are considered invalid although their frequency is so low as to be inconsequential. In addition, a number of SSNs are exactly equal to the employer identification number. These are invalid, primarily because they have too few digits. In any instance where a SSN is used for more than one person on a firm's UI wage report or does not have the required number of digits (including zeros), the SSN is considered invalid.

The possibility that someone fraudulently uses a valid SSN assigned to someone else poses a special problem. First of all, the SSN will show up multiple times across firms in one quarter for workers with different surnames. With this information alone, it is not possible to know which worker is using the SSN fraudulently and who the valid owner of the number is. If one of the SSN/surname pairs shows up in the data initially in a quarter by itself, this is the pair that is considered valid and all other duplicates with different surnames are considered invalid.

Examining the patterns of incidence of different types of invalid SSNs suggests that some types are firm generated rather than worker generated. Figure 4 illustrates the incidence patterns across types of invalid SSNs in construction. The percent of workers with SSNs having a high area number or out-of-sequence group number displays the growth in undocumented workers whereas the incidence of SSNs for other reasons exhibits a flat to declining, highly seasonal pattern.[8] The strong seasonal nature of the other invalid reasons suggests that firms are temporarily assigning invalid SSN numbers to workers before having time to gather the information for the purpose of record keeping/reporting. Or, firms may decide to not bother obtaining a SSN for workers who will only be employed a very short time.[9]

Figure 5 plots the prevalence of undocumented workers in the seven broadly defined sectors with the highest incidences. The concentration of workers in these sectors was also identified nationally by Capps, Fortuny and Passel (2007)[20]. The pattern of growth is also consistent with their estimate that 72 % of unauthorized immigrants in Georgia arrived in the last 10 years.

Capps et al. (2007)[20] estimate that 4.5% of the workforce in Georgia was undocumented

[8] See Baker, Hoefer and Rytina (2010) for an analysis of the undocumented population in the U.S.

[9] Indeed, a worker has 90 days to resolve a discrepancy that results in the receipt of a "no-match" letter from the Social Security Administration. The employee may be long gone before such a letter is even received.

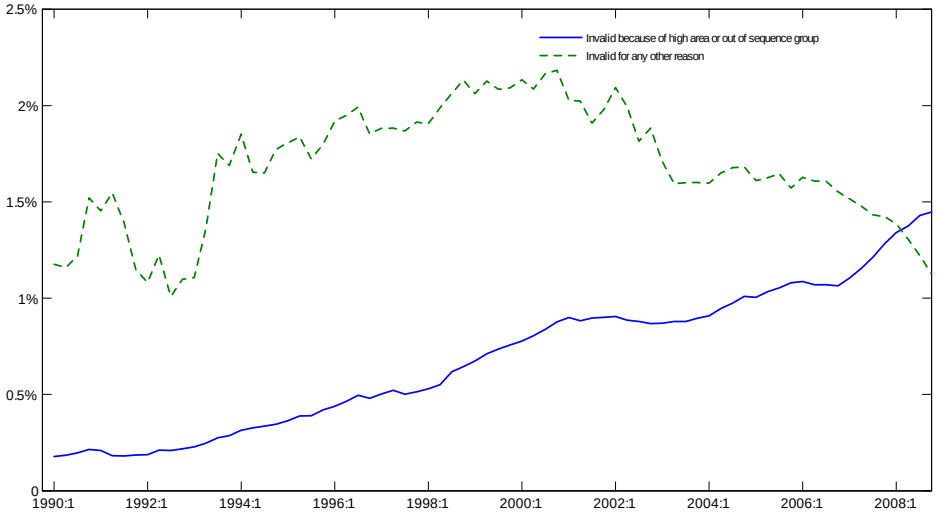

Figure 4: Percent of workers with invalid SSN, by reason, 1990:1-2008:4

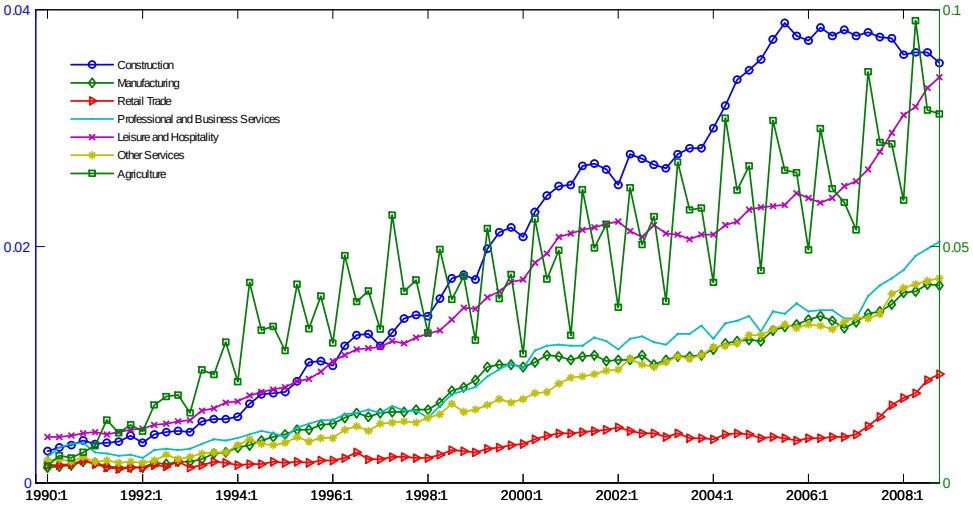

Figure 5: Percent of undocumented workers by broad industry, 1990:1-2008:4. Agriculture is measured on the right axis.

in 2004. In our sample 1% of workers are classified as undocumented in 2004, implying that the sample used for the analysis in this paper is capturing about 22% of all undocumented workers in the state of Georgia. This is a respectable representation given that to be included in the sample all workers have been included on the firm's wage report in the first place and we are being very conservative in the identification of workers as undocumented. Note that the identification process we use in this paper does not make any assumptions about whether the employer knows a worker is documented or undocumented. In addition, the goal of the conservative identification process was to end up with a sample in which we can have a high degree of confidence that the sample is representative of the undocumented workforce, not to actually count the number of undocumented workers in Georgia.

4.2.2 Are Undocumented Workers Correctly Identified?

There are several reasons we are confident that the sample of undocumented workers is representative. First of all, the rate of growth seen in both the number and percent of undocumented workers identified in Georgia matches closely the rate of growth in the Social Security Administration's (SSA) earnings suspense file (ESF). The ESF is a repository of social security taxes paid by employers that cannot be matched to a valid name or SSN. Bovbjerg (2006)[15] argues that growth in the ESF reflects growing incidence of unauthorized work in the U.S.

Figure 6 plots the number of workers (panel a) and the percent of workers (panel b) identified as undocumented along with the size of the ESF. This figure shows a remarkable consistency between the growth seen in workers identified as undocumented and the ESF.

Data suggest that between 40% and 60% of Mexicans in the U.S. are undocumented, and that 61% of unauthorized immigrants come from Mexico. Clearly not all Hispanics are undocumented, or vice versa, however using weighted data from the Current Population Survey (CPS), we calculate the average annual growth in total workers and total number of foreign born, Hispanic workers in the U.S. and in Georgia in order to compare growth rates to those in our sample. These results are reported in Table 22. The work force in GA grew faster over the period than the U.S. work force (2.8% vs. 1.4% respectively).

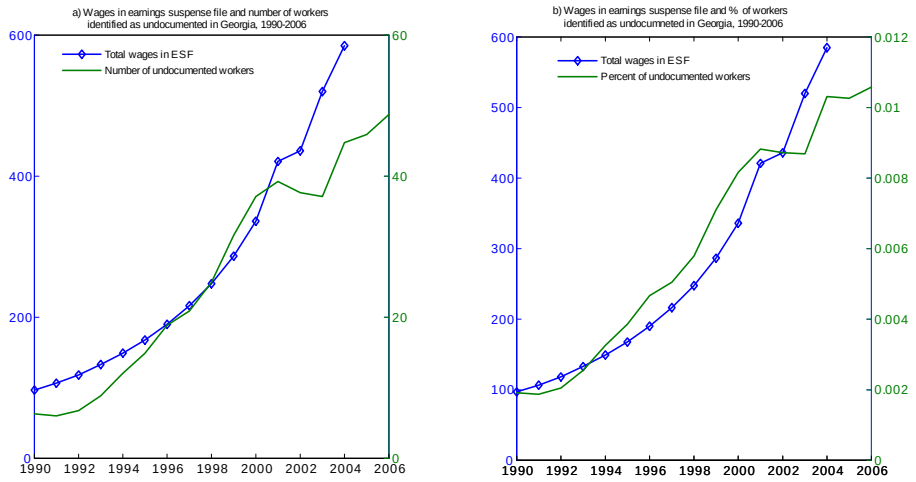

Figure 6: Wages in earnings suspense files and the number and percent of undocumented workers in Georgia, 1990-2006

In addition, the number of foreign born, Hispanic workers in the U.S. grew faster (7% per year) than the overall work force. This observation has been documented by Passel and Cohn (2009b)[64]. More important for us is that the growth rate of foreign born, Hispanic workers in GA (roughly 21% per year), which is much larger than in the U.S. overall is similar to the growth in the number of workers in GA classified here as undocumented (roughly 29%).

The close match in growth rates in the number of workers classified as undocumented with that of the SSA ESF and with the number of foreign born, Hispanic workers in Georgia as measured by the CPS, suggests that the mechanism employed in this paper to identify undocumented workers is accurate. It is clear that not all undocumented workers are being captured in the data, but likely those identified as undocumented are undocumented.

4.3 STYLIZED FACTS

Quantifying differences in the variation of employment of documented and undocumented workers across the business cycle is accomplished in this section by analyzing a series of styl-

Average annual growth rate	
Total number of workers in the U.S.	1.43%
Total number of foreign born, Hispanic workers in the U.S.	7.26%
Total number of workers in Georgia	2.82%
Total number of foreign born, Hispanic workers in Georgia	20.74%
Total number of workers in GA identified as undocumented	29.65%

Table 22: Average annual growth, 1994-2008 in US and GA employment, Hispanic workers and workers identified as undocumented. Source: Current Population Survey, Basic Survey (March) 1994-2006 and authors' calculation

ized facts. The analysis begins with Figure 7, which shows the log of the cyclical components of employment for documented and undocumented workers along with Georgia's gross state product (GA GSP).[10] It is immediately apparent from this figure that undocumented worker employment is much more volatile than documented worker employment. Even slight economic downturns, as was seen in 1997, is accompanied by dramatic swings in undocumented worker employment. In addition, movements of documented worker employment appear to follow movements of and GA GSP are very closely, whereas the peaks and troughs in the undocumented worker series appear to lag those of GA GSP.

Table 23 confirms these observations. We report the standard deviation of the cyclical component of logged employment series for undocumented and documented workers as a measure of the volatility. Over the entire period of analysis, volatility of undocumented worker employment (0.07 log points) is more than three times higher than volatility of documented worker employment (0.02 log points). In addition, while the volatility of documented worker employment has remained constant over the entire period, volatility of undocumented worker employment has dropped from 0.08 between 1990 and 1999 to 0.06 for the last eight years of study (2000 to 2008). Rolling standard deviations for eight quarters shown in Figure 8 further illustrates these two observations; greater volatility of employment of undocumented workers and a clear decline in that volatility over time.

[10] The series for Georgia's Gross State Product is annual, instead we use the quarterly series for Georgia's Personal Income (subtracting transfers) as a proxy. See appendix C.

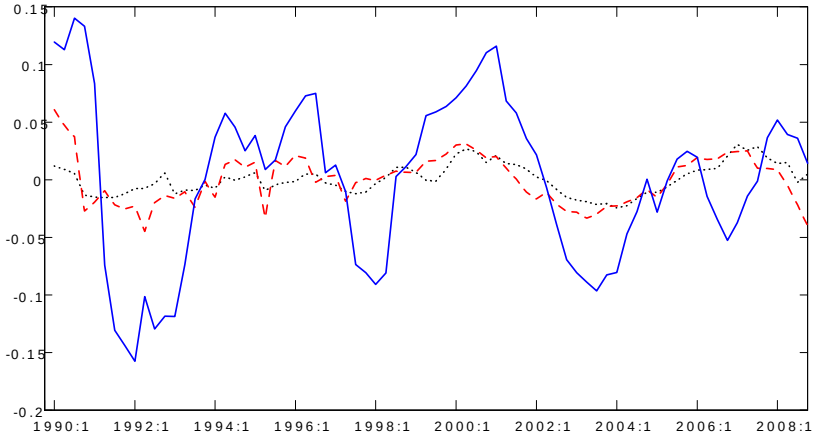

Figure 7: Cyclical component of documented and undocumented employment and output in Georgia, 1990:1-2008:4.

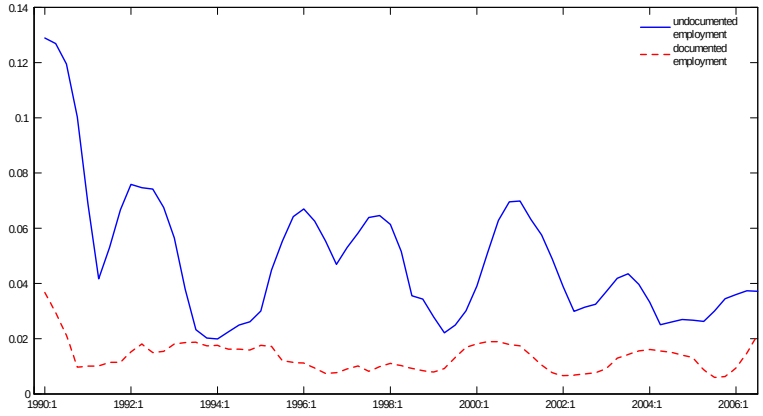

Figure 8: Rolling standard deviations of the cyclical components of undocumented and documented employment

	1990:1-2008:4		1990:1-1999:4		2000:1-2008:4	
	Undocumented	Documented	Undocumented	Documented	Undocumented	Documented
Total	0.07	0.02	0.08	0.02	0.06	0.02
Industries						
Natural Resources and Ag.	0.08	0.03	0.11	0.03	0.05	0.03
Construction	0.09	0.05	0.10	0.06	0.09	0.04
Manufacturing	0.11	0.02	0.14	0.03	0.06	0.02
Trans. & Utilities	0.11	0.02	0.13	0.02	0.08	0.02
Wholesale Trade	0.08	0.03	0.09	0.02	0.07	0.03
Retail Trade	0.12	0.03	0.10	0.03	0.13	0.03
Financial Activities	0.18	0.02	0.20	0.02	0.16	0.02
Information	0.20	0.04	0.15	0.04	0.24	0.04
Prof. & Business Srvcs	0.10	0.03	0.12	0.03	0.08	0.04
Ed. & Health Services	0.14	0.013	0.11	0.016	0.16	0.02
Leisure and Hospitality	0.06	0.03	0.06	0.03	0.06	0.02
Other Services	0.08	0.03	0.10	0.04	0.04	0.01
Skill Intensity						
Low	0.06	0.02	0.07	0.02	0.04	0.02
Medium	0.08	0.03	0.10	0.03	0.06	0.03
High	0.16	0.02	0.12	0.01	0.20	0.01
Labor Intensity						
Low	0.08	0.02	0.10	0.02	0.05	0.02
Medium	0.07	0.03	0.07	0.03	0.06	0.02
High	0.10	0.02	0.10	0.02	0.09	0.02

Table 23: Volatility of the cyclical component of undocumented and documented employment

These patterns of volatility are fairly consistent across industry sectors; for every sector, undocumented worker employment volatility exceeds that of documented workers by an order of two (in Construction) to an order of ten (in Education and Health). However, not all sectors experienced the same moderation in volatility among undocumented worker employment from the 1990's to the 2000's. Volatility ranged from 2.3 times higher in the 1990's in Agriculture to volatility that actually increased from the 1990s to the 2000s (in Retail Trade, Information, and Education and Health). In addition, among documented workers, employment became significantly less volatile between the two time periods in Education and Health and in Other Services. Nonetheless, while not perfectly consistent, the pattern of greater moderation in volatility of undocumented worker employment holds across most sectors.

Grouping sectors based on two characteristics, skill and labor intensity, tells us more about the nature of volatility levels and how they differ across undocumented and documented workers. As we would expect from the literature, low skilled documented employment has a higher volatility (0.026) than high skilled employment (0.017). However, this pattern is the opposite among undocumented workers, high skill undocumented employment displays a higher volatility (0.165) than low skill undocumented employment (0.058). In addition, low and medium skill undocumented employment becomes less volatile in the 2000s, relative to the 1990s, whereas high skill undocumented employment becomes more volatile. This increased volatility among undocumented workers employed in high skill industries may reflect an increased monitoring of valid of SSNs for higher skilled positions.

In terms of labor intensity, we again see an opposite pattern among documented and undocumented worker employment volatility. Whereas employment of undocumented workers in industries with the highest level of labor intensity is more volatile than in industries with the lowest labor intensity (0.097 vs. 0.080), it's the opposite among documented workers. In addition, the degree to which volatility of undocumented worker employment exceeds that of documented worker employment increases with labor intensity of the industry in which the workers are employed. This would make sense as more labor intensive firms also likely have more flexibility in adjusting employment to meet changing demand.

While much of the difference in volatility in employment across documented status is

likely related to differences in skill levels of workers, age, or industries in which workers are employed, the nuances described above across skill and labor intensity, however, suggest that there are some intriguing differences within worker's legal status.

Table 24 presents the correlation of the cyclical components of undocumented and documented employment with U.S. GDP and GAgsp. We observe that the movements of employment of documented and undocumented workers relate differently to overall economic fluctuations. Documented employment is more highly correlated with contemporaneous US GDP (0.76) and GA GSP (0.71) than with lead and lagged values. The correlation declines as one moves in either direction from the current time period. In contrast, the cyclical component of undocumented worker employment is most highly correlated with US GDP and GA GSP lagged two quarters, 0.68 and 0.58 respectively, and declining on either side. This indicates that firms adjust undocumented worker employment with a lag; slower to be terminated in a downturn and slower to be hired on the upswing than documented workers.

U.S. GDP	Documented	Undocumented
t-2	0.54	0.67
t-1	0.68	0.64
t	0.76	0.50
t+1	0.65	0.35
t+2	0.45	0.15
Georgia GSP		
t-2	0.43	0.58
t-1	0.57	0.56
t	0.71	0.50
t+1	0.68	0.39
t+2	0.62	0.28

Table 24: Correlation of cylical components of U.S. GDP and Georgia GSP with documented and undocumented employment

A question arises as to the source of this lag structure. Unlike the labor markets for skilled and unskilled labor, where observed wage differentials are likely reflecting only differences in productivity across these groups of workers. Hotchkiss and Quispe-Agnoli (2010)[44]

provide evidence that about 30% of the observed wage differential between documented and undocumented workers derives from differences in labor supply elasticities. In other words, undocumented workers are paid less than their marginal revenue product. If this is the case, one can imagine a scenario where a firm heading into recession is acutely cost conscious and wants to get the biggest bang for its buck regarding work force reductions. The most expensive workers, for a given level of productivity (documented workers) will be released first. However, this can only be sustained for a short period of time, apparently approximately two quarters, when undocumented workers are released as concerns over productivity overtake efforts of immediate cost cutting. Coming out of a recession, wages have likely fallen so that the cost differential between documented and undocumented workers for a given productivity level has also likely shrunk, in which case employers would prefer to re-hire documented workers first.

Figure 9 focuses more narrowly on the dynamics of documented and undocumented worker employment specifically across recessions. Following the methodology of Jaimovich, Pruitt and Siu (2009)[46], we set the date to 0 for all the NBER dated recessions and follow the cyclical component of both series for 20 quarters following the onset of the recession. We average across all the recessional responses. The graph shows the difference in the magnitudes of the fluctuations of the cyclical components of documented and undocumented employment. The response of undocumented employment to a recession is roughly down by 11% at its trough, whereas for the documented employment it is only down about 3.5%. The average peak to trough response of documented employment is about 7.5% above the trend whereas the peak to trough response of undocumented employment is about 23% above the trend. This implies a nearly 3 times stronger response of the undocumented to employment to a recession on average, and reinforces the greater volatility of undocumented worker employment identified earlier.

We also observe in Figure 9 the difference in the timing of the employment adjustment across the business cycle; documented employment declines (or becomes negative) contemporaneously with the start of the recession, whereas undocumented employment is still positive for the two following quarters, but declines dramatically falling to a greater depth than documented worker employment. Documented employment reaches its trough at period 6, with

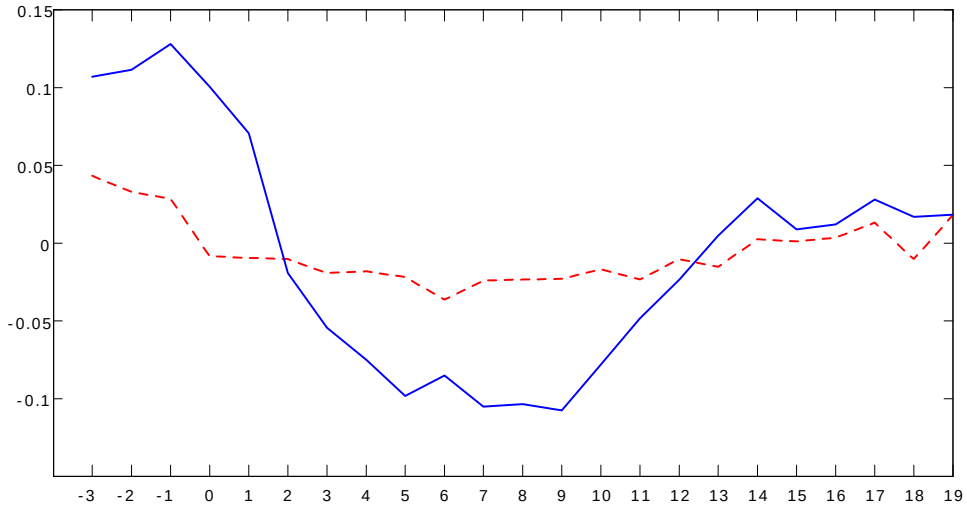

Figure 9: Average response of the cyclical component of documented and undocumented employment: Date 0 is the onset of the recession as identified by NBER

undocumented employment reaching its trough around period 9.

Following Hansen and Prescott (2005)[39], we calculate the depth of cyclical fluctuations in undocumented and documented employment. We average the cyclical components across all periods above and below the trend level for both series. These results also confirm that fluctuations are deeper for undocumented workers, ranging from +5% to -7%, than for documented, whose employment fluctuates between +2% and -2%.

From many different angles, the stylized facts presented here confirm that employment of undocumented workers is more volatile than employment of documented workers across the business cycle. Although not a foregone conclusion, this was not unexpected. Undocumented workers share characteristics with other groups of workers, such as immigrants and the unskilled, who have been found by others to experience more volatile employment than their counterparts (i.e., natives and skilled workers). In addition, as pointed out by Passel and Cohn (2009a)[63] undocumented workers are known to be much younger, on average than the population of documented workers and Jaimovich et al. (2009)[46] has also found that employment among young workers is generally more volatile across the business cycle

than employment among older workers.

4.4 THEORETICAL FRAMEWORK AND QUANTITATIVE ANALYSIS

The previous section illustrated the degree to which employment dynamics of undocumented workers across the business cycle differs from that of documented workers. One of the reasons theorized to lead to these differences in volatility and timing in peaks and troughs is the degree to which documented and undocumented workers are complementary to capital in the production process. Documented workers, typically in possession of higher skills, on average, than undocumented workers, are expected to be employed in jobs which require more intensive use of capital; undocumented workers are expected to be employed in jobs where they are not required to use capital as intensively as documented workers (Dustmann et al. (2010)[30]). This lower complementarity with capital, and the fact that capital inputs are fixed in the short-run, will lead to greater variability in employment as the firm adjusts its production across the business cycle. When firms want to reduce production during a recession (i.e., in the short-run) they will do so by adjusting inputs that are most flexible. Since capital stock is fixed firms cannot adjust the capital stock so they will adjust the input which is more closely substitutable with capital. In the context of this paper, that would likely be undocumented workers, rather than documented workers.

The next subsection discusses a production technology where undocumented labor is more substitutable with physical capital than documented labor. The subsections following that evaluate the performance of this production function in explaining the differences in the volatility of documented and undocumented employment at business cycle frequency.

4.4.1 The Production Technology

In our quantitative analysis, we adapt the production technology used in KORV (2000)[50] and express the output produced in Georgia as follows;

$$Y_t = A_t[\mu U_t^{\theta} + (1-\mu)\{\lambda K_t^{\rho} + (1-\lambda)D_t^{\rho}\}^{\theta/\rho}]^{1/\theta} \tag{4.1}$$

Here U_t denotes undocumented workers, and D_t denotes documented workers. A_t is a neutral technology shock, which can be described by the following stochastic process:

$$A_t = \exp(z_t) \tag{4.2}$$

$$z_t = \phi z_{t-1} + \varepsilon_t \tag{4.3}$$

where $E(\varepsilon_t) = 0$ and $var(\varepsilon_t) = \sigma_\varepsilon^2$

Here $1/(1-\theta)$ corresponds to the elasticity of substitution between undocumented workers and capital-documented labor composite and $1/(1-\rho)$ is the elasticity of substitution between documented workers and physical capital. In this framework, $\theta > \rho$ implies that documented workers are more complementary to capital than undocumented workers.

$$w_t^D = A_t(1-\lambda)(1-\mu)Y_t^{1-\theta}\{\lambda K_t^\rho + (1-\lambda)D_t^\rho\}^{(\theta/\rho-1)}D_t^{\rho-1} \tag{4.4}$$

$$w_t^U = A_t\mu Y_t^{1-\theta}U_t^{\theta-1} \tag{4.5}$$

$$r_t = A_t\lambda(1-\mu)Y_t^{1-\theta}\{\lambda K_t^\rho + (1-\lambda)D_t^\rho\}^{(\theta/\rho-1)}K_t^{\rho-1} \tag{4.6}$$

$$\frac{w_t^D}{w_t^U} = \frac{(1-\lambda)(1-\mu)\{\lambda K_t^\rho + (1-\lambda)D_t^\rho\}^{(\theta/\rho-1)}D_t^{\rho-1}}{\mu U_t^{\theta-1}} \tag{4.7}$$

4.4.2 Parameterization

The first step in our quantitative analysis is to pin down the parameters of the model. There are four parameters that need to be specified. These are the share parameters μ and λ and the elasticity parameters θ and ρ in equation (4.1).

KORV (2000)[50] estimate the value of θ which measures the degree of substitution between unskilled labor and capital or skilled labor in their model as 0.4. Their estimate for ρ which determines the elasticity of substitution between skilled labor and capital is -0.495. We borrow the value of θ and ρ from their study and calibrate μ and λ to match the average

wage bill ratio between documented and undocumented labor in Georgia between 1990 and 2008. To compute the wage bill ratio we calculate the total wage bill for undocumented and documented workers by multiplying the average quarterly wage income with the total number of these workers in the Georgia labor force. Table 25 reports the value of the wage bill ratio in the data and in the model along with the value of which produces this data moment.

	Data moment	Model	Data
$\mu = 0.007$	Wage bill ratio - undocumented and documented labor	6.03	6.03
$\lambda = 0.012$	Income share of labor	56%	56%

Table 25: Calibration result: Data and simulated moment

4.4.3 Simulation Results

In this section we assess the performance of our model in explaining the difference between the volatility of documented and undocumented employment. In other words, we evaluate the importance of different degrees of substitution elasticity between capital and undocumented and documented labor to account for the higher variation of the undocumented employment at business cycle frequency.

Analogous to Castro and Coen-Pirani (2008)[23], we use our parameters, the actual series for capital stock K_t, the number of documented workers D_t, and the series for the relative earnings of documented and undocumented workers w_t^D/w_t^U to obtain a predicted series for undocumented employment $\widehat{U}_t$. Following this we extract the cyclical component of the simulated series $\widehat{U_t^c}$ and compute its standard deviation.

Figure 10 presents the cyclical component of the undocumented employment from the benchmark model compared to its data counterpart. Table 26 reports the cyclical properties of the simulated undocumented employment series. In particular we report the standard deviation of the cyclical component of the undocumented employment produced by our

model and its contemporaneous correlation with that of Georgia's output.

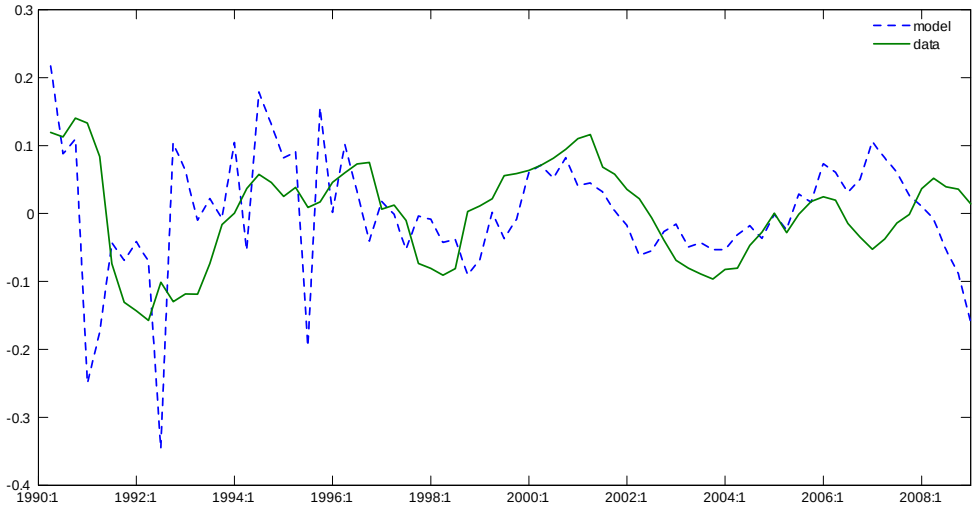

Figure 10: Cylical component of undocumented employment: Model vs. data

	Data	Model
1990:1-2008:4	0.07	0.08
1990:1-1999:4	0.08	0.10
2000:1-2008:4	0.06	0.05

Table 26: Volatility of undocumented employment: Model vs. Data

The model produces a standard deviation of 0.08 for the whole period which is a slight over prediction of the volatility observed in the data for the same period. Looking at the 1990:1-1999:4 and 2000:1-2008:4 periods separately, we observe that the model does well in matching the volatility of the undocumented employment for both sub periods. In particular for the second sub-period covering the quarters between 2000 and 2008, our model generates an undocumented employment series with a standard deviation of 0.05. The standard deviation of the cyclical component of the undocumented employment is measured as 0.06 in the data for the same period implying that our model can explain 80% of the cyclical

variation of undocumented employment after 1999. For the 1990-1999 period, the volatility of the model simulated undocumented employment is 0.1, which is approximately 20% higher than the actual standard deviation which is 0.08 in the data.

These results suggest that the model performs well in explaining the higher volatility of the undocumented labor in Georgia for the 1990-2008 period. In particular exploiting the differences in the elasticity of substitution between the two groups of workers and capital we can explain an important portion of the higher variance of the undocumented labor during the 2000-2008 period. The model also captures the reduction in the volatility of undocumented employment observed in the data after 1999. The model's prediction for the volatility of the undocumented employment series is slightly higher for the 1990-1999 period which results in a larger standard deviation for the whole period.

Although we are interested in the high frequency behavior of the undocumented employment, we also evaluate our model's ability in matching the long-term behavior of the series. Figures 11 and 12 compare the model and data values for undocumented employment and its trend component. Under the current set of parameters, we see that the model has limited capability in explaining the long-run behavior of undocumented employment. The model captures the increase in undocumented employment for the 1990:1-1995:4 period. After that we observe a steeper increase in the data whereas the model produces a slowly increasing then decreasing series for undocumented employment.

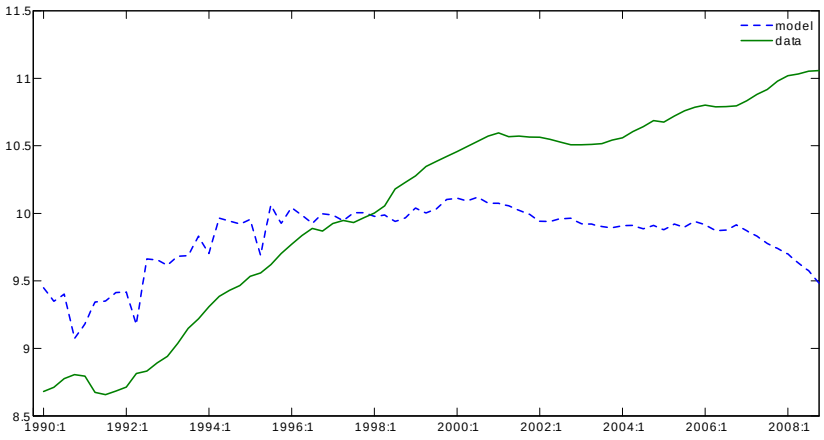

Figure 11: Undocumented employment: Model vs. data

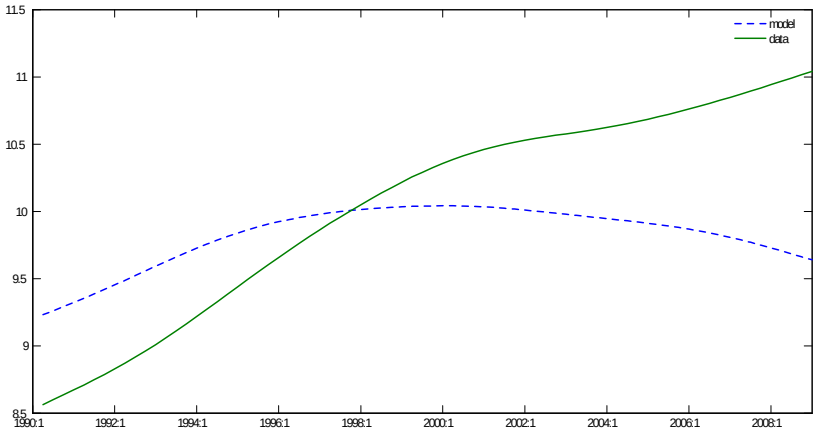

Figure 12: Trend component of undocumented employment: Model vs. data

4.5 CONCLUSION

The sensitivity of employment of individuals belonging to different demographic groups to business cycles has been analyzed in the literature in recent years. The existing studies have examined how the employment of skilled vs. unskilled, young vs. old, and natives vs. immigrant workers behave differently from each other at business cycle frequency. In this paper we have studied the same dimension for documented and undocumented workers. Using quarterly data on the number of employed documented and undocumented workers in Georgia between 1990 and 2008, we have shown that the employment of undocumented workers is more volatile than the documented ones. Industry-level employment figures for these workers reveal that the same volatility difference is observable in different industries as well as the aggregate Georgian economy. We provide an explanation of this data fact by using a simple production technology where firms use capital, documented and undocumented labor and the undocumented labor is more substitutable with capital. The results from our quantitative analysis show that with this production technology we can explain an important portion of the higher sensitivity of undocumented workers' employment to the business cycles in Georgia.

The results in this paper suggest that employment of undocumented workers may provide a degree of flexibility to the production process of firms that hire them. The consistency of these results with those found by others when comparing the employment volatility of unskilled, young, and immigrant workers, compared with employment volatility of skilled, older, and native workers, respectively, is not surprising; undocumented workers are typically low skilled, young, and are, by definition, immigrants. Although undocumented workers make up a much smaller group of workers than the low-skilled, young, or immigrants, this role of providing additional production flexibility means that immigration reform that restricts the number, or affects the status of undocumented workers would also curtail the flexibility in labor markets that employers currently have, increasing hiring costs along with the likelihood of an increase in consumer prices.

As we acknowledge among the discussion of our results, the model has some shortcomings in explaining the long-run behavior of the employment of undocumented workers. We plan

to address this issue in future work. There are alternative possible theories which explain the differential cyclical response of undocumented employment. These theories are listed in Dustmann et al. (2010)[30]. Equilibrium search models form the foundation of one explanation. These models originate from the work of Diamond (1982)[28], Mortensen (1982)[59] and Pissarides (1985)[69]. In these models, a worker is hired under the condition that a successful match is established between the firm and the worker. Unemployment is an equilibrium outcome due to the cost of opening a vacancy. The unemployment rate fluctuates along the business cycles together with the labor productivity of workers hence the pay-off from opening vacancies. These models can provide an explanation for the higher volatility of the employment of undocumented workers. The key insight proposed by Dustman et al. (2010)[30] is based on the different seperation rates observed among workers. If a worker has lower seperation rate, i.e. he is expected to stay with the firm longer, his average productivity rather than his current productivity is more important for the firm. When the seperation rates are higher for a group of workers, it is the current productivity that matters for the hiring decision hence posting vacancies. Therefore differences in seperation rates might be one factor which cause the documented and undocumented workers to respond differently to business cycle fluctuations even though they have identical productivity.

Another factor linked to differences in seperation rates which might generate a higher cyclical volatility for undocumented workers is the lower cost of firing undocumented workers. Undocumented workers are not covered by provisions such as severance payments, or limitations on dismissal of employees. This makes not only firing but also hiring these workers easier during downturns and expansions of the economy. An interesting avenue for future research is to study the business cycle properties of undocumented workers' employment in a general equilibrium model incorporating the differences in the firing costs for both groups of workers.

An alternative theory which can provide an explanation for the differential response of undocumented labor to expansions and recessions of the economy is the existence of dual labor markets. Saint-Paul (1996)[72] and Bulow and Summers (1986)[18] discusses these labor markets. In Bulow and Summers (1986)[18] there is a homogenous group of workers and two types of jobs - primary and secondary- which have different monitoring

technologies. In the primary sector where the monitoring technology is costly workers are paid higher wages to prevent them from shirking. In the secondary sector, workers are paid lower wages since it is less costly to monitor them. Differences in monitoring costs between the two sectors generate higher volatility of employment in the secondary market since the neutral productivity shocks affect the employment in these markets more directly. Saint-Paul (1996, pp. 45-58)[72] elaborates on these dual markets. In his framework, workers in the primary sector have a higher incentive to shirk in anticipation of layoffs by the firm. Therefore the firms abstain from firing these workers during the downturns of the economy otherwise they have to increase their wages to higher levels to prevent shirking. One remedy for firms to adjust labor without raising the wage burden too much is to shift the burden of adjustment to workers in the secondary market who are easier to monitor therefore are not paid efficiency wages. In an economy where undocumented workers are employed in secondary markets, the variation in their employment during the business cycles are larger. This is another direction in which we plan to explore further the underlying reasons for the higher sensitivity of undocumented workers to business cycles.

Illegal immigrants which account for a majority of the undocumented labor force are mostly evaluated in terms of the fiscal burden they create for the economy. However based on the dual markets theory we can claim that the existence of a more flexible secondary market helps firms to avoid paying unnecessarily high efficiency wages to documented workers in anticipation of firings due to negative productivity shocks. In other words, the existence of a lower segment of the labor markets dominated by illegal workers results in a lower unemployment rate in the economy; however, the documented primary sector workers are paid smaller wages. An interesting area for future research is a welfare analysis of undocumented employment or illegal immigration in a general equilibrium efficiency wage model with dual labor markets which are subject to productivity shocks. The impact of the segmented labor market structure on the total labor earnings in the economy is ambiguous because as mentioned above, the existence of a secondary market where undocumented workers are employed results in lower wages and higher employment level among the primary sector workers. The equilibrium labor income taxes, total savings hence interest rates depend on the total wage earnings in the economy which all together are important determinants of

the overall welfare. A general equilibrium model with the specified features will allow an extensive evaluation of the undocumented workers' impacts on the welfare of documented ones taking into account the changes observed in all prices and tax rates in the economy.

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APPENDIX A

CHAPTER 1 APPENDIX

A. DATA

Labor Supply Measures

Canadian data for the 1981-2008 period comes from Statistics Canada. I made use of two different micro data sets. The first one is the Survey of Consumer Finances data for individuals aged 15 years and over between income years 1981 and 1997. Survey of Consumer Finances data set is terminated after 1997. Starting with 1998, Survey of Labour and Income Dynamics micro data set is the source for annual cross-sectional income estimates and other individual level variables. Unfortunately, 1997 and 1998 SLID data sets do not provide information on the nativity status of the individual. Therefore I construct the labor supply data for the 1999-2008 period and use interpolation to find the labor supply data for 1998. The data source for the U.S. is the IPUMS database. I use 1980, 1990 and 2000 Census 2% samples and 2008 CPS data to construct the aggregate labor supply measures for the U.S.

The sample consists of employed wage and salary workers between ages 16 and 65. I drop individuals with 0 or unknown hours worked. For the construction of composition adjusted labor hours by two skill groups, I follow KORV (2000). A brief description of the aggregation of the individual labor inputs are provided below

Aggregation of individual labor inputs

All the individuals included in the sample are divided into demographic groups according to their age, nativity, education level and sex. There are 10 five year age group, two nativity groups (native and foreign born), two sex groups, and 4 education groups. In total there are 160 demographic groups.

The four education groups are less than high school, high school, some college and college graduates. In SCF data, the variable indicating education level of the individual is *educ*. In SLID data this variable is *hleveg*. I construct the education groups as follows;

a) Less than high school: All individuals with less than 12 years of schooling. (*educ*<4 or hleveg<6)

b) High school graduates: All individuals 12 or 13 years of schooling. (*educ*=4 or *educ*=5, or hleveg=6)

c) Some college: All individuals with some post secondary education or post secondary certificate or

diploma. (educ=6 or educ=7 or 8≤*hleveg*≤10)

d) College graduate: All individuals with a university degree. (*educ*=8, *hleveg*=11 or *hleveg*=12)

For each of the demographic subgroups, I construct the composition adjusted total hours worked. To be able to construct the average labor supply by each demographic group, I first find the labor input of each individual by multiplying the usual hours worked in a week (*hrswrk*, *ushours* after 1989) with the weeks worked last year (*wkswrk*).

$$l_{i,t} = h_{i,t} wk_{i,t}$$

where $l_{i,t}$ is the total hours worked in a year, $h_{i,t}$ is the hours worked last week, and $wk_{i,t}$ is the weeks worked last year.

The SLID data set does not provide data for usual hours worked in a week, but there is information about total hours paid (*alhrp*), weeks worked in all jobs (*wksem*) during the year. Dividing *alhrp* by *wkesm,* I obtain hours worked in a week $h_{i,t}$. Since the hours worked in a week is top coded at 65 hours in SCF data, I apply the same top coding to SLID data as well.

The next step is to aggregate the total hours worked by individuals and find the labor input for each demographic subgroup. The labor input for each of the 160 demographic groups are calculated as follows.

$l_{g,t} = \frac{\sum_{i \epsilon g} l_{i,t} \mu_{i,t}}{\sum_{i \epsilon g} \mu_{i,t}}$ where $\mu_{i,t}$ are the weights for each person(*revweig* or *weight* after 1989 in SCF, *icswt* or *wtcsld* in SLID) and $l_{g,t}$ is the total hours worked by all the individuals belonging to group g.

Hourly wages

To find the hourly wages of each demographic subgroup I first obtain the hourly wages by individuals as follows;

$$w_{i,t} = \frac{y_{i,t}}{l_{i,t}}$$

where $y_{i,t}$ total annual income (*wagsal*) and $l_{i,t}$ is the total hours worked by each individual. The SLID data set provides information on hourly wages (*cmphrw*). I use this variable for hourly wages after 1999. The hourly wages by each demographic subgroup are;

$$w_{g,t} = \frac{\sum_{i \epsilon g} w_{i,t} \mu_{i,t}}{\sum_{i \epsilon g} \mu_{i,t}}$$

Labor Inputs and Hourly Wages by Skilled and Unskilled

The next step is to aggregate the labor inputs by all the demographic subgroups into skilled and unskilled categories. The sample is divided into skilled and unskilled according to their education levels. All the individuals with a university degree and above are considered as skilled.

When aggregating the demographic subgroups into two skill groups, I use efficiency weights and calculate a weighted sum of the labor inputs of each demographic subgroup included in that skill group. There are different alternatives one can use as efficiency weights. I use the average hourly wages by each demographic

group between 1981 and 2008. This gives the skilled and unskilled labor inputs and hourly wages which are the following;

$$L_{j,t} = \sum_{g \epsilon G_{j,t}} l_{g,t} \bar{w}_g \mu_{g,t}$$

$$W_{j,t} = \frac{\sum_{g \epsilon G_{j,t}} l_{g,t} \mu_{g,t} w_{g,t}}{L_{j,t}} \; for \; j = s, u$$

Construction of the Capital Stock

To compute the skill premium, I need to obtain the real value of the capital equipment stock for Canada. In order to obtain the real values of the capital equipment stock, a price deflator for the machinery and equipment capital is necessary. Statistics Canada provides the price index for machinery and equipment. Table 327-0016, provides quarterly price index for machinery and equipment until 2005. The base year is 1986 in this series. Table 327-0042 provides the price index starting from 1997 until 2010 with base year 1997. I use the first series for the 1981-1997 period and the second series for the 1997-2008 period. I convert the base year to 2002 in both series and combine the two data to obtain a price index for machinery and equipment for the 1981-2008 period. As pointed out by Cummins and Violante (2002) for the U.S. data, the price index for machinery and equipment provided by NIPA does not take into account changes in the quality of these goods. Therefore they construct a quality adjusted machinery and price index for the U.S. Unfortunately, there is no similar study for Canada. However Cummins and Violante (2002) calculate the average growth rate of the quality improvement as 2.5% for the 1960-2002 period. I assume that Canada also experienced the same improvement in the quality of machinery and equipment and adjust the price index for machinery and equipment by this quality factor. The quality adjusted price index for Canada is calculated as follows;

$$p_t = P_{m,t} \times (1.025)^{1981-t} \forall t = 1981, ..2008$$

The data series for machinery and equipment capital is available in table 031-0002 (Flows and stocks of fixed non-residential capital by NAICS classification). I use the end year net stock by geometric discounting series for the year 1980-2007 and deflate it by the quality adjusted price index p_t.

$$K_{e,t}^{\text{real}} = \frac{K_{e,t}^{\text{nominal}}}{p_t}$$

B. **DECOMPOSITION OF LOG CHANGE IN RELATIVE SKILLED LABOR**

$$\Delta \log(\frac{S_T}{U_T}) = \Delta \log(\frac{S_M}{U_T} + \frac{S_N}{U_T}) \simeq \frac{(\frac{S_M}{U_T} + \frac{S_N}{U_T})_{t+1} - (\frac{S_M}{U_T} + \frac{S_N}{U_T})_t}{(\frac{S_M + S_N}{U_T})_t}$$

$$\frac{(\frac{S_M}{U_T} + \frac{S_N}{U_T})_{t+1} - (\frac{S_M}{U_T} + \frac{S_N}{U_T})_t}{(\frac{S_M + S_N}{U_T})_t} = \frac{((\frac{S_M}{U_T})_{t+1} - (\frac{S_M}{U_T})_t) + ((\frac{S_N}{U_T})_{t+1} - (\frac{S_N}{U_T})_t)}{(\frac{S_M}{U_T})_t + (\frac{S_N}{U_T})_t}$$

$$= \frac{(\frac{S_M}{U_T})_t \frac{((\frac{S_M}{U_T})_{t+1} - (\frac{S_M}{U_T})_t)}{(\frac{S_M}{U_T})_t} + (\frac{S_N}{U_T})_t) \frac{((\frac{S_N}{U_T})_{t+1} - (\frac{S_N}{U_T})_t)}{(\frac{S_N}{U_T})_t)}}{(\frac{S_M + S_N}{U_T})_t}$$

$$= (\frac{U_T}{S_M + S_N})_t (\frac{S_M}{U_T})_t \frac{((\frac{S_M}{U_T})_{t+1} - (\frac{S_M}{U_T})_t)}{(\frac{S_M}{U_T})_t} + (\frac{U_T}{S_M + S_N})_t (\frac{S_N}{U_T})_t \frac{((\frac{S_N}{U_T})_{t+1} - (\frac{S_N}{U_T})_t)}{(\frac{S_N}{U_T})_t)}$$

$$= (\frac{S_M}{S_M + S_N})_t \frac{((\frac{S_M}{U_T})_{t+1} - (\frac{S_M}{U_T})_t)}{(\frac{S_M}{U_T})_t} + (\frac{S_N}{S_M + S_N})_t \frac{((\frac{S_N}{U_T})_{t+1} - (\frac{S_N}{U_T})_t)}{(\frac{S_N}{U_T})_t)}$$

which can be rewritten as;

$$\Delta(\frac{S_T}{U_T}) = \Delta(\frac{S_M}{U_T})\frac{S_M}{S_T} + \Delta(\frac{S_N}{U_T})\frac{S_N}{S_T}$$

APPENDIX B

CHAPTER 2 APPENDIX

A. DATA SOURCES AND CONSTRUCTION

Measurement of college graduates and less than college graduates

As mentioned in the paper the data for the initial state in 1980 is extracted from 1981 SCF (Survey of Consumer Finance) and the data for the final state in 2008 is extracted from SLID(Survey of labor and Income Dynamics). 1981 SCF microdata has a variable called *educ* which indicates the education level of individuals. The education categories available are no schooling or elementary, 9 or 10 years of elementary school 11 years of elementary school 12 years of elementary school, 13 years of elementary school some post secondary , post secondary certificate and university degree. The data set does not provide any information on the years of schooling of individuals therefore I consider individuals with a university degree as college graduates and all the remaining ones as less than college graduates. To keep the definition of a college graduate consistent across two data sets, I also consider the individuals with a bachelor's degree and above as college educated and all individuals below bachelor's degree as less than college graduate. The education variable used to classify individuals is *hleveg.* This variable can have 12(01-12) different values in 2008 SLID data. A value of 11 indicates that the individual has a bachelor's degree and a value of 12 indicates that the individual has a university certificate above bachelor's degree. So I classify an individual with hleveg$\geq$11 as a college graduate and everyone else as less than college educated.

Measurement of Immigrants

I include individuals aged above 22 in my immigrant population. The variable *immig* gives information about the immigration status of an individual in the 1981 SCF sample. *immig* takes 8 values(1-8) indicating the immigration status of an individual. *immig>1* implies that the individual is immigrant and each value indicates the 10 year interval during which the individual entered Canada. 2008 SLID microdata set has two different variables for the immigrant status of an individual. These two variables are *immst* and *yrimmg.* For immigrants *immst* takes a value of 1 and *yrimmg* gives information about how many years ago the individual came to Canada. To categorize individuals into natives and immigrants, I use the *immst* variable.

Use of sample weights

To find the relative share of each group, I calculate the total weight of the relevant group and find the ratio of this sum to the total weight of the bigger group. The variables which indicate the sample weight of each individual are *revweig* and *wtcsld* in the 1981 SCF and 2008 SLID samples, respectively.

Efficiency units

The efficiency units are calculated for 4 different groups which are college graduate natives and immigrants and less than college graduate natives and immigrants. To calculate the age efficiency units for each group, I follow Krusell et al.(2000) methodology and compute the average value of hourly wages between 1981 and 2008 as efficiency weights for each group at all ages. The sample includes full time full year wage and salary workers aged between 18-65 (22-65 for college graduate natives and immigrants). I also exclude all individuals with an hourly wage below $1.

The first step is the calculation of hourly wages for each individual in the sample. 1981-1997 SCF microdata does not provide information about the hourly wages of individuals. However the variable *wagsal* is the total wage and salary earnings of the individual. To find the hourly wages, I calculate the total hours worked for an individual by multiplying the weekly hours worked (*hrswrk*) and the weeks worked in a given year (*wkswrk*). Having obtained total hours worked, I divide the annual wage and salary earnings by the total hours worked and get the hourly wages. In Krusell et al.(2000) notation, I compute

$w_{i,t} = \frac{y_{i,t}}{l_{i,t}}$ where $y_{i,t}$ total annual income and $l_{i,t}$ is the total hours worked by each individual. For the SLID data between 1999 and 2008 has a variable which indicates the hourly wages of an individual so I do not need to make the same calculation for this period. Instead I use the the variable *cmphrw* variable. Having merged all samples, I find the weighted average hourly wage for each group at all ages between 18 and 65. To formulate this weighted average,

$w_j^{o,e} = \frac{\sum_i w_{i,j}^{o,e} \mu_i^{o,e}}{\sum_i \mu_{i,j}^{o,e}}$ where i indicates the individual, $j = 18,..65$ and $o \in \{n, m\}$ $e \in \{c, h\}$. Lastly I normalize the weighted hourly wage of each age, nativity, and skill group by the weighted hourly wage of the age 40 individuals in the same nativity and skill group. So the efficiency weights used in the model are as follows;

$$\varepsilon_j^{o,e} = \frac{w_j^{o,e}}{w_{40}^{o,e}}$$

The following figure illustrates the age efficiency units for the natives.

Relative price of machinery and equipment

The price of machinery and equipment relative to consumer nondurables illustrated in figure 2 is calculated using the price index for machinery and equipment and the price index for consumer non-durables available through StatCan. The price index for machinery and equipment between 1980 and 2008 is the combination of two different price index series. The first one covers the period between 1980 and 2005. The source is table 327-0016- machinery and equipment price indexes (MEPI), base year 1986. The second data set covers the period between 1997-2008. The source is the Table 327-0042 Machinery and equipment price indexes (MEPI) base year 1997. The price index for consumer non-durables between 1980 and 2008 is

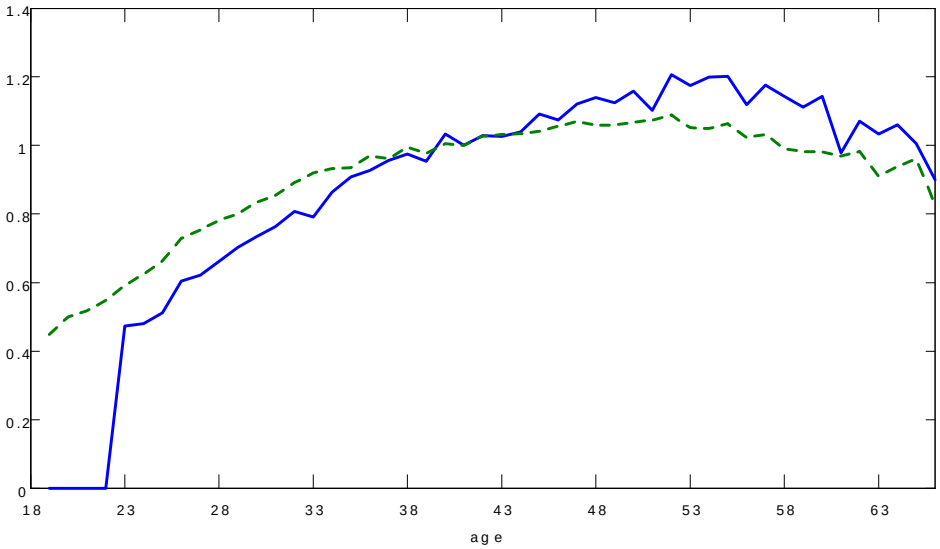

Figure 13: Age efficiency unit profiles: 1981-2008 Average. Solid Line- College graduates, Dashed Line- High school graduates

extracted from table 326-0021 CPI 2005 basket with base year 2002. Both machinery and equipment price index series are quarterly therefore as a first step in calculating the relative price of machinery and equipment, I average across quarters in a year to find the annual price index for machinery and equipment. The second step is to form a uniform base year across the three price index series. To achieve that, I normalize the two price series for machinery and equipment by the value of the price index in 2002, and convert the machinery and equipment price indices to base year 2002. To get a machinery and equipment price index which covers the whole period between 1980 and 2008, I combine the two price indices for machinery and equipment. Comparing the common data points (1997-2005) of the two series shows that there is a difference in the levels of the two series. In order to avoid any jumps that may occur in the combined data set, I compute the annual growth rate of the price index for machinery and equipment between years 2005 and 2008. Applying these growth rates to the data points starting from 2005 I extrapolate the price index of machinery and equipment until 2008. The next step is to find the relative price of machinery and equipment. I divide the machinery and equipment price index series by the CPI for consumer nondurables which gives me the relative price of machinery and equipment between 1980 and 2008.

Log hourly wage	1981	1991	2001	2008
College education	0.346*	0.36*	0.394*	0.422*
age	0.065	0.078	0.100	0.11
age squared	-0.001	-0.001	-0.001	-0.001
male	0.335	0.270	0.204	0.183

Table 27: Regression results of log hourly wages on a college education dummy, age, age squared, and a male dummy. indicates significance at 1 percen

B. LIFE CYCLE ASSET PROFILES

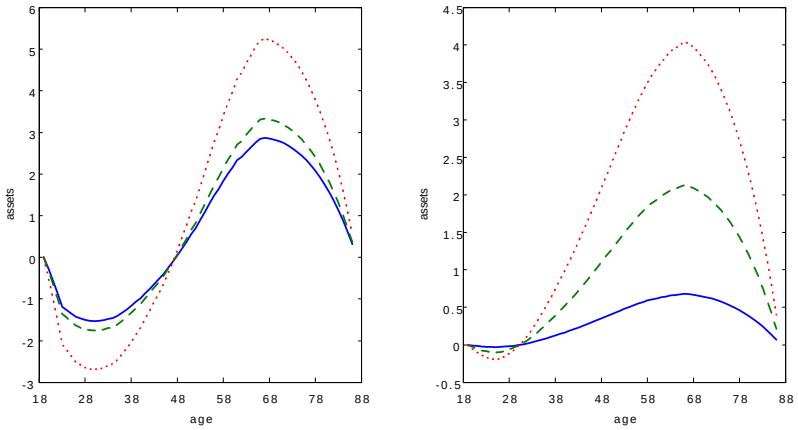

Figure 14: Life cycle asset profiles of natives. Left Panel: College graduates, Right Panel: Less than college graduates. Solid line- lowest ability, Dashed line- median ability, Dotted line- highest ability

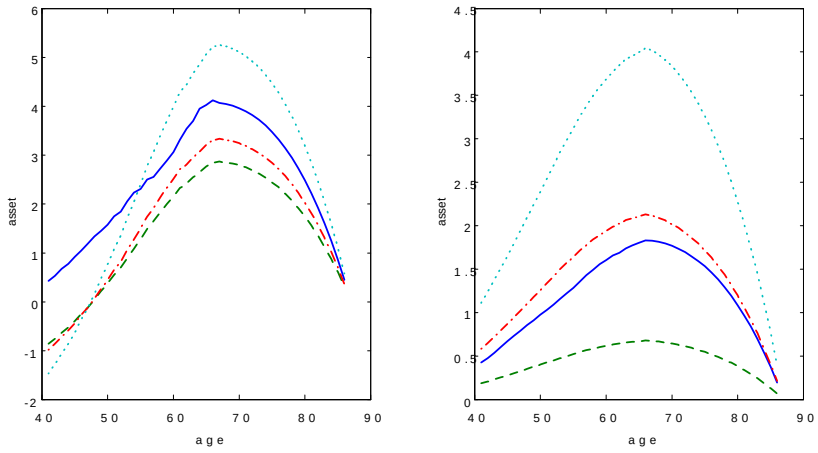

Figure 15: Life cycle asset profiles of immigrants and natives

APPENDIX C

CHAPTER 3 APPENDIX

A. SKILL AND LABOR INTENSITY CATEGORIES

Industry Skill Classification

Each industry is assigned a skill intensity based on the weighted average of educational attainment of workers in that industry, using the Current Population Survey for 1994. This year was chosen since this is the first year in which the nativity (place of birth) of respondents is reported. For each industry, the percent of workers with less than a high school education (LTHS), a high school education (HS), some college (SCOLL), college degree (COLL), and graduate education (GRAD) is calculated. If the share of workers with less than high school degree is higher than the sum of individuals with high school, some college and college education in an industry, that industry is classified as low skill. In the opposite case, the industry is classified as high skill. If the share of workers with below high school education is equal to the share of workers with the high school, some college and college education is classified as medium skill.

About 23% of the industries are classified as high skill, 15% at low skill, and 62% at medium skill. Some examples of low skill industries include agriculture, some manufacturing, and accommodation and food services. Medium skill industries include construction, retail trade, some manufacturing, some education and health, and arts and entertainment. High skill industries include the information sector, electronic computer manufacturing, the financial sector, and some education and health.

Industry Labor Intensity Classification

Labor share for each industry is based on coefficients from the U.S. Input-Output (I-O) Benchmark Tables 2002 (http://www.bea.gov/industry/index.htm#benchmark_io). The labor share coefficient is defined as the share of compensation of employees (wage bill) in total industry output. Compensation of employees includes wages and salaries and their supplements.

Total industry output is the sum of the products consumed by the industry, compensation of employees, taxes on production and imports less subsidies, and gross operating surplus.

Coefficients are calculated at the four-digit NAICS industry level and grouped in 3 levels. Level 1 includes coefficients from 0.01 to 0.29 (cost of labor accounts for from one to 29 percent of total output),

level 2 includes coefficients equal to 0.30 to 0.39, and level 3 includes coefficients from 0.40 to 0.79.

Examples of industries in Level 1 are oilseed and grain farming, oil and gas extraction; petroleum refineries; automobile manufacturing; electronic computer manufacturing; real estate; snack food and breakfast cereal manufacturing; doll, toy, and game manufacturing; telecommunications; cutlery, utensil, pot, and pan manufacturing; rail transportation; and book publishers. In Level 2, we find footwear manufacturing; printing; dry-cleaning and laundry services; tire manufacturing; watch, clock, and other measuring and controlling device manufacturing; fitness and recreational sports centers; child day care services; insurance agencies; brokerages; wholesale and retail trade; and food services and drinking places. Level 3 includes cut and sew apparel contractors, custom computer programming services, scientific research and development services, elementary and secondary schools, nursing and residential care facilities, home health care services and employment service.

B. PROXY FOR GEORGIA GROSS STATE PRODUCT

Georgia's Gross State Product is an annual series and to obtain a proxy for a quarterly series we look at US gross domestic product, Georgia personal income less transfers. We calculated the correlations between the log of these series and the log of Georgia's GSP as well as the correlation between the cyclical components of these series, and we concluded to use personal income less transfers. The results of these correlations are as follows:

Correlation of logged series	GA GSP
U.S. GDP	0.98
GA Personal income-Transfers	0.99
Correlation of cyclical components	
U.S. GDP	0.70
GA Personal income-Transfers	0.77

Table A1: *Source Haver analytics*