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by

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Abstract

Immigrant assimilation is a major issue in many countries. While most of the literature studies assimilation through a human capital framework, we examine the role of job search assimilation. To do so, we estimate an equilibrium search model of immigrants operating in the same labor market as natives, where newly arrived immigrants have lower job offer arrival rates than natives but can acquire the same arrival rates according to a stochastic process. Using Canadian panel data, we find substantial differences in job offer arrival and destruction rates between natives and immigrants that are able to account for three fifths of the observed earnings gap. The estimates imply that immigrants take, on average, 13 years to acquire the native search parameters. The job search assimilation process generates 18% earnings growth for immigrants in a 40 year period following migration.

1 Introduction

Immigration has always played a major role in Canada. It serves as an important source of labour for the country, and therefore successful integration of immigrants in the labour market has direct implications for the Canadian economy. There is a large literature documenting and analyzing Canadian immigration patterns and the relative success of Canadian immigrants by landing cohort and immigrant type in the labour market.[1] The vast majority of this research, and for that matter research on immigrant assimilation in all countries, has been based on the standard human capital model.[2]

The lower earnings of immigrants upon arrival is attributed to their lower levels of human capital specific to the host country, and the catch-up of their earnings is explained by their stronger incentives to invest in host-country specific human capital. Numerous papers have been written studying the relationship between immigrants' earnings and observable characteristics related to their human capital acquired in the source country as well as that acquired in the host country. The set of characteristics often includes information on educational attainment and labour market experience in each country as well as age and literacy level at immigration.[3]

A new approach to the immigrant-native earnings gap has recently emerged and is asking how much of the gap is due to differences in job search behavior.[4]. There are a number of reasons to expect that new immigrants face a different search environment than natives. First, it is natural to think that newly arrived immigrants are simply not accustomed to local practices of job search. Second, the same factors accounting for the native-immigrant human capital gap may contribute to job search differentials between natives and immigrants. Examples include qualification recognition and language fluency. Possible difficulties of having foreign credentials recognized by employers may slow the application process, while language fluency likely plays an important role in the job search and interview processes.[5]

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[1]See, for example, Abbott and Beach (2011), Green and Worswick (2010), Xue (2010), Baker and Benjamin (1994), and Sweetman and Warman (2013).

[2]Chiswick (1978); Borjas (1999)

[3]See, for example, Skuterud and Su (2012).

[4]Examples include Chassamboulli and Palivos (2010), Ortega (2000) and Liu (2010), and Gupta and Kromann (2013)

[5]Oreopoulos (2011) and Dechief and Oreopoulos (2012) provide evidence that employers discriminate against job applicants with foreign-sounding names in hiring, associating with them low local language skills.

It is also important to consider the role of social networks in job search. Differences in networks formed and network usage between natives and immigrants are likely to be reflected in differences in job search outcomes between natives and immigrants. A number of papers have documented that workers utilize friends and relatives when searching for a job, and recent work indicates that social networks are especially important for newly-arrived immigrants. Using the Longitudinal Survey of Immigrants to Canada (LSIC), Goel and Lang (2012) find that having close friends or relatives in Canada significantly increases the likelihood that recently arrived immigrants will find employment within the first six months of their arrival.[6] Other examples include Munshi (2003) who documents that use of social networks is very common in acquiring employment for Mexican migrant workers in the United States, and Frijters et al. (2005) who document that immigrants in the U.K. tend to rely on their social networks to obtain a job more than natives.

Taking this idea of differences in job search behaviour one step further this paper uses search theory to examine the role of job search in immigrant assimilation. The idea being that not only can immigrants invest in human capital once they enter the host country to achieve earnings assimilation but that they can also learn more about the labour market and how to better search for a job. This idea is similar to that proposed by Daneshvary et al. (1992) who take the view that immigrants acquire more information about the host country's labour market the longer they have been there and this results in earnings that are much closer to their potential or maximum attainable earnings. Here we take a different approach and develop a Burdett-Mortensen style general equilibrium search model with two types of workers: immigrant workers and native workers. Importantly, new immigrants face more search frictions than natives but over time can assimilate such that they face the same search frictions as natives.

The Burdett-Mortensen equilibrium search model has been used to explain earnings differentials between many different groups, including the male-female earnings gap (Bowlus, 1997), the black-white earnings gap (Bowlus et al., 2001; Bowlus and Eckstein, 2002), and the family earnings gap (Zhang, 2012). This paper extends this tradition to the immigrant earnings gap. The Burdett-Mortensen search model can generate earnings differentials because how fast workers are able to generate job offers

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[6]Interestingly the structural estimates of their search model reveal that the presence of close ties in Canada increases the likelihood of receiving a job offer but does not help in finding better offers.

has direct implications for their earnings. More specifically, the theory predicts that the distribution of the earnings of a group with higher job offer arrival rates dominates that of a group with lower rates. If new immigrants have search behaviour that is characterized by lower job offer arrival rates than those of native born workers, the model will predict an immigrant earnings gap. However, if there is an assimilation process such that immigrants can learn how to search more effectively over time and increase their arrival rates of job offers, then the model predicts that this assimilation of the search process will provide a mechanism for earnings convergence.

To conduct our analysis we build on the model developed by Zhang (2012) to study the difference in earnings between mothers and non-mothers. Zhang extended the Burdett-Mortensen equilibrium search model in two important ways. First, her model has two groups of workers with different job offer arrival rates conducting job search in a single labour market.[7] Second, her model allows one of the groups (in her case non-mothers) to transition to the other group (mothers). Firms then take these transitions into account when posting offers and equilibrium earnings differentials result. This model setting fits our purposes well as it is important for us to model both the job search differences between immigrants and natives, but also the possibility that immigrants can assimilate and become like natives in their job search behaviour. In addition, we also capture the general equilibrium effects of both the presence of the immigrants in the labour market and their assimilation behaviour on not only their earnings levels but also on those of natives.

We estimate the model using duration and earnings data from the Canadian Survey of Labour and Income Dynamics (SLID) to measure the difference in job offer arrival rates between new immigrants and natives, and estimate how long it takes immigrants to acquire the same job search parameters as natives. Then, we study the implications of this assimilation process for the earnings gap between immigrants and natives, and immigrants' earnings growth.[8]

Our estimation results indicate that there are substantial and significant differences in job offer arrival and job destruction rates between natives and newly arrived immigrants. Job offer arrival rates for immigrants are 36% lower while unemployed

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[7]Prior to Zhang (2012) the standard method was to assume that the two groups were operating in separate markets. Because of the assimilation process this standard method is not suitable for our setting.

[8]Papers using SLID to study immigrant assimilation include Skuterud and Su (2012), Hum and Simpson (2004) and Hum and Simpson (2000).

and 93% lower while employed. The latter figure has substantial consequences for the amount of search frictions faced by immigrants. Immigrants receive almost no job offers during an employment spell compared to natives who receive nearly 2 offers. Importantly, these differences are able to account for three quarters of the observed earnings differential between natives and immigrants.

Our results also indicate that it takes immigrants 13 years, on average, to assimilate and acquire the same search parameters as natives. Studies of earnings assimilation using the human capital framework have reported a wide range of estimates of the time it takes for assimilation. In a recent study on assimilation of Canadian immigrants Skuterud and Su (2012) find an initial gap of 0.29 log points is halved after 8 years and a slower narrowing subsequently. Thus our results on the search component are consistent in magnitude with the human capital based assimilation literature.

The remainder of the paper is organized as follows. The next section describes the model and its implications for earnings. Section 3 discusses the estimation strategy and data. The estimation results are given in Section 4 followed by concluding remarks in Section 5.

2   Equilibrium Search Model

2.1   Environment

As noted above our model is a version of the equilibrium search model in Zhang (2012). Here we describe the model noting the differences between immigrant and native workers. In the model, time is continuous and the economy is in a steady state. There are a large number of firms and workers in the labour market, with the population of the workers normalized to 1. All workers are either native or immigrant workers. The measure of immigrant workers is denoted by $\mu \in (0, 1)$.

There are two types of immigrant workers. A type 1 immigrant worker represents an individual new to the country and unfamiliar with its labour market. A type 2 immigrant worker represents an immigrant who has lived in the country for a sufficiently long period and as a result has acquired the same level of knowledge of the local labour market as native workers. A type 1 immigrant worker may become a type 2 immigrant worker over time. This event is modeled as a Poisson process with

arrival rate η.

All workers are either unemployed or employed, and search for jobs both on and off the job. If workers are unemployed, they receive b, the flow value of non-market time while unemployed. The arrival of job offers is modeled as a Poisson process. For native-born workers and type 2 immigrant workers, the job offer arrival rate is λ_0 if they are unemployed and λ_1 if they are employed. Because of their lack of knowledge about the labour market, it takes type 1 immigrant workers longer to receive a job offer, on average. For type 1 immigrant workers, the job offer arrival rate is $\alpha_0 \lambda_0$ while unemployed and $\alpha_1 \lambda_1$ while employed, where $0 < \alpha_i < 1$ for $i = 0, 1$.

All firms have constant returns-to-scale production technologies with labour being their sole input. We assume that both native and immigrant workers are equally productive within a firm. However, the productivity of a worker differs across firms. Specifically, we assume that there are Q types of firms that differ in their marginal productivity of labour. For a type j firm, p_j denotes the per-worker output of the firm, where we assume $p_j < p_{j+1}$ for $j = 1, 2, \ldots, Q - 1$.

Each firm posts a wage offer w to attract workers. We assume that it must post the same offer to both native and immigrant workers.[9] The distribution of offers in equilibrium is given by $F(w)$ with support $[\underline{w}, \overline{w}]$, and workers and firms meet each other through random search. This implies that a worker draws a wage offer from $F(w)$ when receiving a job offer. A worker-firm match can be terminated exogenously at rate δ_1, forcing the worker into unemployment.

To ensure that both types of immigrants are present in the steady-state, we assume that workers exit from the labour market permanently according to a Poisson process with arrival rate δ_2. Exiting native workers are replaced by unemployed native workers, while all exiting immigrant workers are replaced by unemployed type 1 immigrant workers.

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[9]That is immigrants and natives are competing in the same labour market. If firms could post separate offers, then effectively the two markets would be separate. This assumption does tie our hands somewhat in the degree to which the model can generate an immigrant earnings differential. However, we prefer this specification of direct competition both in terms of the assimilation process and in terms of understanding the impact the lower search frictions of the immigrants has on the native workers.

2.2 Workers' Problem

After receiving an offer, the worker decides whether to accept or reject it. Let V_n^u denote the value of unemployment to native workers, and let $V_n^e(w)$ denote the value to native workers of being employed at wage w. Then V_n^u is characterized by the following Bellman equation:

$$rV_n^u = b + \lambda_0 \int_{\underline{w}}^{\overline{w}} \left[\max\left(V_n^e(x), V_n^u\right) - V_n^u \right] dF(x) - \delta_2 V_n^u. \tag{1}$$

The left-hand side of equation (1) represents the payoff to unemployment, while the right-hand side shows how the payoff is derived. The first term on the right-hand side is the monetary value of non-market time. The remainder is the option value of unemployment due to possible transitions out of unemployment. There are two possible transitions from unemployment. First, at arrival rate λ_0, a worker receives a job offer, and accepts it if it yields a higher value than unemployment. Second, at arrival rate δ_2, a worker permanently leaves the labour market and receives the value of zero thereafter.

Similarly, $V_n^e(w)$ is characterized by the following Bellman equation:

$$rV_n^e(w) = w + \lambda_1 \int_{\underline{w}}^{\overline{w}} \left[\max\left(V_n^e(x), V_n^e(w)\right) - V_n^e(w) \right] dF(x)$$
$$+ \delta_1\left(V_n^u - V_n^e(w)\right) - \delta_2 V_n^e(w). \tag{2}$$

The left-hand side of equation (2) represents the payoff to a native working at wage w. The first term on the right-hand side is the wage flow. The remainder indicates the option value accruing from possible transitions to different states. There are three possible transitions from the current job. First, at arrival rate λ_1, a worker receives a new job offer, and decides whether to accept the offer. Second, at arrival rate δ_1, a worker is separated from the current job. Third, a worker permanently leaves the labour market at rate δ_2.

The optimal search strategy of workers has a reservation wage property. While employed, workers accept any job offer that specifies a higher wage than the current job. While unemployed, workers optimally set a reservation wage, and accept any job that offers a wage above the reservation wage, and reject offers otherwise. Let R_n denote the optimal reservation wage for unemployed native workers. R_n satisfies

condition $V_n^e(R_n) = V_n^u$. Together with equations (1) and (2), the condition yields

$$R_n = b + \int_{R_n}^{\overline{w}} \frac{(\lambda_0 - \lambda_1)\overline{F}(x)}{\rho + \lambda_1 \overline{F}(x)} \, dx, \qquad (3)$$

where $\overline{F}(w) \equiv 1 - F(w)$ and $\rho \equiv r + \delta_1 + \delta_2$. Notice that type 2 immigrant workers face the same problem as native workers. Thus this group of immigrants acts according to the same reservation wage strategy as native workers.

Type 1 immigrant workers face a slightly different process. Let V_m^u denote the value of being unemployed and $V_m^e(w)$ denote the value of being employed at wage w to type 1 immigrant workers. Then V_m^u is determined by the following equation:

$$rV_m^u = b + \alpha_0 \lambda_0 \int_{\underline{w}}^{\overline{w}} \left[\max(V_m^e(x), V_m^u) - V_m^u \right] dF(x) + \eta \left(V_n^u - V_m^u \right) - \delta_2 V_m^u. \qquad (4)$$

When compared with equation (1), equation (4) shows that the option value of unemployment for type 1 immigrants differs from that of natives and type 2 immigrants in two ways. First, as shown in the second term on the right-hand side, the arrival rate of job offers is scaled by α_0. Second, as the third term on the right-hand side shows, a possible change in type also contributes to the option value of unemployment. Similar points are made for $V_m^e(w)$, which satisfies the following Bellman equation:

$$rV_m^e(w) = w + \alpha_1 \lambda_1 \int_{\underline{w}}^{\overline{w}} \left[\max \left(V_m^e(x), V_m^e(w) \right) - V_m^e(w) \right] dF(x)$$
$$+ \eta \left[\max \left(V_n^e(w), V_n^u \right) - V_m^e(w) \right] + \delta_1 \left(V_m^u - V_m^e(w) \right) - \delta_2 V_m^e(w). \qquad (5)$$

Again the differences from equation (2) are that the job offer arrival rate is scaled by α_1, and the optimal response to a change in type is accounted for in the option value.

When a type 1 immigrant working at wage w becomes a type 2 immigrant worker, it is optimal to quit the current job if $V_n^e(w) < V_n^u$. Since $V_n^u = V_n^e(R_n)$, and $V_n^e(w)$ is increasing in w, such behavior is optimal only if $w < R_n$.

It is straightforward to show that $V_m^e(w)$ is increasing in w, implying that the optimal search strategy of type 1 immigrant workers is a reservation wage strategy as well. Employed type 1 immigrant workers accept any job offer that pays a higher wage than the current job, and unemployed type 1 immigrant workers optimally set a cut-off wage level, denoted by R_m, and accept any job offering a wage that exceeds

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R_m and reject otherwise.

The following result shows the equation characterizing R_m:

Proposition 1. R_m *solves the following equation:*

$$R_m = b + \int_{R_m}^{\overline{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx + \int_{R_n}^{\overline{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx$$

$$- I(R_m \geq R_n) \int_{R_n}^{R_m} \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx,$$

where R_n is given by equation (3).

Proof. See Appendix A.

When $\eta = 0$, type 1 immigrant workers never assimilate by changing their types. In this case, their problem is similar to that of native workers except for the differences in job offer arrival rates. That is, R_m satisfies essentially the same nonlinear equation as R_n, since the second and third terms on the right-hand side of equations (4) and (5) vanish. When $\eta > 0$, in contrast, type 1 immigrant workers need to take into account events that may occur after their type changes in order to set their reservation wage strategies.

The condition determining the ranking between R_m and R_n is given in Lemma 1.

Lemma 1. $R_m \leq R_n$ *if and only if*

$$\int_{R_n}^{\overline{w}} \left(\frac{\rho + \eta + \lambda_0\overline{F}(x)}{\rho + \lambda_1\overline{F}(x)} - \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\rho + \eta + \lambda_1\overline{F}(x)}{\rho + \lambda_1\overline{F}(x)} \right) dx \geq 0,$$

Proof. See Appendix A.

The above condition is difficult to verify analytically except in a small number of cases. However, the following two examples show that the ranking between R_m and R_n is in general ambiguous. First suppose $\alpha_1 = 1$, then the left-hand side becomes

$$\int_{R_n}^{\overline{w}} \frac{\rho + \eta + (1 - \alpha_0)\lambda_0\overline{F}(x)}{\rho + \lambda_1\overline{F}(x)}dx \geq 0,$$

establishing $R_m \leq R_n$. In contrast, if $\alpha_0 = 1$, then the left-hand side of the equation becomes

$$\int_{R_n}^{\overline{w}} \frac{(\alpha_1 - 1)(\rho + \lambda_1\overline{F}(w))\lambda_1\overline{F}(w)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)} < 0,$$

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concluding $R_n < R_m$.

2.3 Firms' Problem and Equilibrium Wage Offer Distribution

The equilibrium wage offer distribution is derived from firms' optimal behaviour. Given the technology, a firm's profit is the product of the per-worker profit margin and the stock of workers in the firm. Letting $l(w)$ denote the steady-state measure of workers available to a firm offering wage w, the steady state profit flow of a type-j firm is written as

$$\pi_j(w) = (p_j - w)l(w).$$

Each firm posts a wage to maximize the steady-state profit flow.

Lemma 1 indicates that in general R_m is not equal to R_n. As pointed out in Mortensen (1990), the equilibrium wage offer distribution may have gaps in the support when workers with different reservation wages operate in a single labour market. To avoid complications resulting from this feature of the wage offer distribution, we follow Zhang (2012) and assume that there is an exogenously set minimum wage in the economy, denoted by w_{min} which is set higher than both R_m and R_n. Given this simplifying assumption, all wage offers will be accepted by all unemployed workers.

The labour stock at a firm paying w can be divided into three components based on the characteristics of workers:

$$l(w) = l_n(w) + l_{m1}(w) + l_{m2}(w)$$

where $l_n(w)$ denotes the steady-state mass of natives working for a firm offering wage w, and for $y \in \{1, 2\}$, $l_{my}(w)$ denotes the steady-state mass of type y immigrants working for a firm offering wage w. These three objects are derived by balancing the steady-state flows generated by job-to-job, unemployment-to-job and job-to-unemployment transitions made by workers. In particular, native workers make these transitions in the same way as modeled in Burdett and Mortensen (1998) with the exception that permanent exit from the labour market is a possible transition. The per-firm native worker stock is therefore given by

$$l_n(w) = \frac{\lambda_0 \delta(\lambda_1 + \delta)}{(\lambda_0 + \delta)(\delta + \lambda_1 \overline{F}(w))^2}(1 - \mu)$$

where $\delta \equiv \delta_1 + \delta_2$. For immigrant workers, the steady-state flow analysis is analogous to that of Zhang (2012) such that the per-firm stocks of type 1 and type 2 immigrant workers are respectively given by[10]

$$l_{m1}(w) = \frac{\alpha_0 \lambda_0 \delta_2 (\delta + \eta)(\delta + \eta + \alpha_1 \lambda_1)}{(\alpha_0 \lambda_0 + \delta + \eta)(\delta_2 + \eta)\big(\delta + \eta + \alpha_1 \lambda_1 \overline{F}(w)\big)^2} \mu,$$

and

$$l_{m2}(w) = \frac{\lambda_0 \eta (\delta + \lambda_1)\big(\delta(\delta + \eta) + \delta_1 \alpha_0 \lambda_0\big)}{(\eta + \delta_2)(\delta + \lambda_0)(\eta + \delta + \alpha_0 \lambda_0)\big(\delta + \lambda_1 \overline{F}(w)\big)^2} \mu$$
$$+ \frac{\lambda_0 \eta \delta_2 \alpha_0 (\delta + \eta)\big((\delta + \lambda_1)(\delta + \eta + \alpha_1 \lambda_1) - \alpha_1 \lambda_1^2 F(w)^2\big)}{(\eta + \delta_2)(\eta + \delta + \alpha_0 \lambda_0)\big(\delta + \lambda_1 \overline{F}(w)\big)^2 \big(\delta + \eta + \alpha_1 \lambda_1 \overline{F}(w)\big)^2} \mu.$$

Note that $l_n(w)$, $l_{m1}(w)$ and $l_{m2}(w)$ all depend on w only through $F(w)$, the quantile of w in the offer distribution. Because of this property, it is convenient to express the per-firm labour force in terms of the wage quantile when characterizing the equilibrium offer distribution. To this end, define $l^*(y)$ with domain $[0, 1]$ by $l^*(y) = l(F^{-1}(y))$.

Following Mortensen (1990), several properties of the equilibrium hold. First, all firms with the same productivity level earn the same steady-state profit flow in equilibrium. Second, the wage offer from a higher productivity firm should be at least as high as the one from a lower productivity counterpart. Third, the highest wage offer made by a type j firm corresponds to the lowest wage offer made by a type $j+1$ firm. Fourth, $\underline{w} = w_{min}$. Finally, $F(w)$ is implicitly defined by the following equal profit conditions:

$$(p_j - w_{Lj})l^*(F(w_{Lj})) = (p_j - w)l^*(F(w)) \text{ for } w \in [w_{Lj}, w_{Hj}], \tag{6}$$

with $w_{L1} = \underline{w}$ and $w_{Hj} = w_{Lj+1}$ for $j \in \{1, 2, ..., Q - 1\}$.

Let $\gamma_0 = 0$, and for $j = 1, 2, \ldots, Q$, let γ_j denote the fraction of firms whose labour productivity is p_j or less. Given the equilibrium condition, firms with labour productivity equal to or less than p_j offer wages equal to or less than w_{Hj}, and firms with the higher productivity offer wages above w_{Hj}. Therefore $F(w_{Hj}) = \gamma_j$ for

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[10]Unlike Zhang (2012), the present paper does not model transitions in and out of nonparticipation of workers. Therefore, the results in this paper are obtained by setting the relevant transition parameters to zero in her model.

$j \in \{1, ..., Q\}$, and equation (6) yields

$$(p_j - w_{Hj-1})l^*(\gamma_{j-1}) = (p_j - w_{Hj})l^*(\gamma_j) \text{ for } j \in \{1, \ldots, Q\}. \tag{7}$$

For each firm type j, equation (7) characterizes the upper- and lower-bounds of possible wage offers made by firms of the given type. This equation can be used to recover p_j from observed wage data. This property of the equilibrium is exploited in estimation.

2.4 Implications for Native-Immigrant Wage Gap

Given the offer distribution of wages $F(w)$, the earnings distribution of workers is characterized by the flows generated by the steady-state job-to-job, unemployment-to-job, job-to-unemployment transitions. Let $G_n(w)$ represent the steady-state earnings distribution among native workers. This takes the standard form:

$$G_n(w) = \frac{\delta F(w)}{\delta + \lambda_1 \overline{F}(w)}. \tag{8}$$

Analogously, let $G_{m1}(w)$ and $G_{m2}(w)$ denote the steady-state earnings distributions for type 1 and type 2 immigrants, respectively. From Zhang (2012), we have that these distributions are, respectively, given by

$$G_{m1}(w) = \frac{(\delta + \eta)F(w)}{\delta + \eta + \alpha_1 \lambda_1 \overline{F}(w)}. \tag{9}$$

and

$$G_{m2}(w) = \frac{\left(\delta(\eta + \delta) + \alpha_0\lambda_0\delta_1\right)(\delta + \eta + \alpha_1\lambda_1\overline{F}(w)) + (\delta + \eta)(\delta + \lambda_0)\delta_2\alpha_0}{(\delta + \lambda_1\overline{F}(w)(\alpha_0\delta_2 + \alpha_0\lambda_0 + \delta + \eta)(\delta + \eta + \alpha_1\lambda_1\overline{F}(w))}F(w). \tag{10}$$

Equations (8), (9) and (10) establish that these three distributions can be ranked unambiguously in terms of the first-order stochastic dominance. The following proposition states this result.

Proposition 2. $G_n(w)$ *first-order stochastically dominates* $G_{m1}(w)$ *and is first-order stochastically dominated by* $G_{m2}(w)$.

Proof. See Appendix A.

The first-order stochastic dominance of $G_{m2}(w)$ over $G_n(w)$ may not be intuitive since both of the relevant groups share the same search parameters. The reason can be thought of as an age-effect. Since an immigrant worker starts as a type 1 immigrant and later become a type 2 immigrant, type 2 immigrants have, on average, more labour market experience and, therefore, more time to improve their earnings through job-to-job transitions. In contrast, the native worker group includes workers who are new to the labour market and have not had a sufficient time to move up the earnings distribution. Therefore the difference in the average length of time spent in the labour market between these two groups generates the earnings gap between them. Analogously, the native group has on average has longer labour market experience than the type 1 immigrant group. This difference contributes to the ranking between the earnings distributions of these groups. Moreover, the higher job offer arrival rate on the job for the native group also widens the earnings gap between natives and type 1 immigrants.

Even though the native earnings distribution lies between those of type 1 and type 2 immigrant workers, it first-order stochastically dominates the earnings distribution for the whole immigrant population once we account for the steady-state composition of the immigrant population. Proposition 3 establishes this result.

Proposition 3. *Let $G_m(w)$ denote the earnings distribution for all immigrant workers. Then $G_m(w)$ is first-order stochastically dominated by $G_n(w)$.*

Proof. See Appendix A.

Finally, we examine the implications of the model for the earnings dynamics for both natives and immigrants by deriving the age profiles of their earnings distributions, and show that the model can generate earnings convergence between native and immigrant workers.

To this end, let $G_n(w; a)$ be the earnings distribution for native workers with labour market experience given by a. Similarly let $G_m(w; a)$ be the earnings distribution for immigrant workers with host country labour market experience given by a. The following proposition establishes that $G_n(w; a)$ and $G_m(w; a)$ have the same limit.

Proposition 4. *For given $w \in [\underline{w}, \overline{w}]$,*

$$\lim_{a \to \infty} G_n(w; a) = \lim_{a \to \infty} G_m(w; a) = \frac{\delta_1 F(w)}{\delta_1 + \lambda_1 \overline{F}(w)}.$$

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Proof. See Appendix A.

The result in Proposition 4 is driven by the gradually increasing share of type 2 immigrants among all immigrants with the same level of (potential) experience. The model predicts that the share of type 1 immigrants among all immigrants with a given labour market experience declines as the time spent in the host country's labour market increases. Therefore, a group of immigrants with sufficiently long labour market experience mostly consists of type 2 immigrants, who behave like native workers. As a result, the earnings distributions converge.

3 Estimation

3.1 Estimation Procedure

The parameters to be estimated are those governing event arrivals (λ_0, λ_1, δ_1, α_0, α_1 and η), wage cuts ($\underline{w}, \{w_{Hj}\}_{j=1}^{Q}$), and those representing the productivity heterogeneity of firms ($\{(p_j, \gamma_j)\}_{j=1}^{Q}$). Estimation is performed by the maximum likelihood procedure developed by Bowlus et al. (1995, 2001) and Bowlus (1998) and then modified by Zhang (2012).[11]

First, we use the lowest and highest wages observed in data for the estimates of $\underline{w}$ and w_{HQ}. Then the following two-stage optimization routine is repeated until the log-likelihood value converges. In the first stage, while fixing the event arrival parameters, we maximize the log-likelihood function by sampling values from the wages earned by native workers and use them for the estimates of $w_{H1}, ..., w_{HQ-1}$. In the second stage, while fixing the wage-cut levels, the log-likelihood function is maximized over the event arrival parameters with a standard iterative optimization routine. Note that every time the objective function is evaluated at a new guess, γ_j and p_j are calculated from the other parameters. Specifically, given equation (8), γ_j is calculated by

$$\gamma_j = \frac{(\delta + \lambda_1)\hat{G}_n(\hat{w}_{Hj})}{\delta + \lambda_1 \hat{G}_n(\hat{w}_{Hj})},$$

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[11]There are two other parameters in the model: δ_2 and μ. These are calibrated before performing the estimation procedure described in this section. Specifically, μ, the proportion of immigrants among the worker population, is set at 0.212 based on the comparable number for 2001. The arrival rate of permanent exit from the labour market is set at 0.0024, which implies that workers on average spend 35 years in the labour market.

where $\hat{G}_n(w)$ is the empirical cumulative distribution function of the wages earned by native workers, and p_j is calculated by

$$p_j = \frac{w_{Hj}l^*(\gamma_j) - w_{Hj-1}l^*(\gamma_{j-1})}{l^*(\gamma_j) - l^*(\gamma_{j-1})}.$$

from equation (7).

Let θ denote the set of parameters that we aim to estimate, and x_i be a list of variables of individual i. The log-likelihood function is written as

$$\ell(\theta) = \sum_{i=1}^{N} \left[(1 - \chi_i) \ln L_n(\theta; x_i) + \chi_i \ln L_m(\theta; \tau_i, x_i) \right]$$

where $L_n(\theta; x_i)$ and $L_m(\theta; \tau_i, x_i)$, respectively, denote the likelihood contributions for native workers and immigrant workers; χ_i is an indicator variable taking 1 if individual i is an immigrant and 0 otherwise; and τ_i denotes individual i's time since migration. We write $L_m(\theta; \tau_i, x_i)$ as the mixture of likelihood contributions for immigrants of different types. Let $L_{m1}(\theta; x_i)$ and $L_{m2}(\theta; x_i)$ denote the likelihood contribution of type 1 and type 2 immigrants, respectively, and let π_i denote the probability that immigrant i is type 1 at the start of the survey. Then the likelihood contribution for an immigrant worker is given by $L_m(\theta; \tau_i, x_i) = \pi_i L_{m1}(\theta; x_i) + (1 - \pi_i) L_{m2}(\theta; x_i)$, and the log-likelihood function can be rewritten as

$$\ell(\theta) = \sum_{i=1}^{N} \left[(1 - \chi_i) \ln(L_n(\theta; x_i)) + \chi_i \ln \left(\pi_i L_{m1}(\theta; x_i) + (1 - \pi_i) L_{m2}(\theta; x_i) \right) \right]. \quad (11)$$

The structural model dictates that the length of time in which an immigrant remains as a type 1 since migration is an exponential random variable with parameter η. Thus $\pi_i = e^{-\eta \tau_i}$. The expressions for $L_n(\theta; x_i)$, $L_{m1}(\theta; x_i)$ and $L_{m2}(\theta; x_i)$ are given in the Appendix B.

3.2   Identification

Identification of the structural parameters other than α_0, α_1 and η follows Bowlus et al. (1995) with the parameters governing firms' productivity heterogeneity identified from the observed earnings distribution and the native search parameters identified from the relevant duration and transition data. Specifically, λ_0 is identified from

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unemployment durations of the natives in the data. Job durations and transitions at the end of job spells help to identify λ_1 and δ_1.

The immigrant job search parameters, α_0 and α_1 are identified from differences in unemployment durations and job durations between natives and recently immigrated individuals as well as differences in unemployment rates. η is identified from variation in spell durations of immigrants with respect to years since migration as well as changes in the earnings distribution with respect to years since migration.

3.3 Data

To estimate our model we need panel data on both immigrant and native populations. We, therefore, make use of the Canadian SLID, which is a household longitudinal survey containing a wide range of information on the labour market experiences, educational activities and attainment, and demographic characteristics of individuals residing in the country. The survey has several waves, each of which follows respondents for 6 years. The first wave started in 1994, and a new wave was introduced every three years such that two contiguous waves overlap for 3 years. Every January, the survey asks respondents about their labour market activities and/or schooling in the previous year, enabling the construction of their employment histories.

For this paper, the third and fourth waves of the survey are used to construct the estimation sample in order to ensure that it contains a sufficient number of immigrant observations. The third wave covers the period from 1999-2004 and the fourth wave from 2002-2007. Instead of pooling the 9 years of data we construct employment histories only from 2002 on for both waves. This results in a shorter panel for the third wave, but aids in maintaining the stationarity assumption of the model by not introducing large business cycle effects between the late 1990s and early 2000s.[12] We use cross-section sample weights from 2002 to address issues of attrition.

We restrict the estimation sample to male individuals aged between 20 and 55 in the beginning of 2002, and exclude respondents who were institutionalized for more than 6 months or who died during the survey period. Respondents are also excluded from the sample if information on their educational attainment or key demographic characteristics, such as the country of birth or years since migration, are missing. In

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[12]In practice, however, survey non-response or missing information did not allow us to follow every respondent for the intended period. Rather than excluding these respondents from the estimation sample, if we encounter a problem, we censor the job history at that point.

addition, to keep the sample population as homogeneous as possible, we impose a restriction on the educational attainment of individuals. Specifically, the estimation sample contains only respondents who had some post-secondary schooling or a post-secondary diploma excluding master's degree or above. Finally, our model concerns individuals who are active labour force participants. Thus, we attempt to include only those who are either working or searching for jobs at any given time. To this end, we exclude individuals who were mainly in school, were in retirement, or were disabled or had a long-term illness.

The above model does not consider schooling decisions and, therefore, only captures immigrant assimilation through post-schooling labour market experience. Thus, it is only relevant for immigrants who completed their schooling before moving to Canada. However, not every immigrant respondent in SLID meets this modeling assumption. In fact, there are ample cases in which we suspect that individuals moved to Canada and then went through schooling activities.[13] Including those individuals in the estimation may, therefore, be problematic as various studies argue that there are differences in labour market outcomes between immigrants who were educated in Canada and those who were not.[14] Although SLID contains information on schooling activities during the survey, it provides less information on schooling undertaken before the survey.[15] To address this complication, we exclude immigrants who migrated to Canada before age 20 as a rough approximation for the desired sampling restriction.

We construct individual labour market histories by first identifying all the jobs held during the survey period. We define a job by an employment relationship with a particular employer, and to be counted as a job spell in our data set an employment relationship needs to last for more than 30 days and have 30 or more usual weekly hours of work.

While the model in this paper does not consider multiple job holding, it is not uncommon to observe individuals who worked for more than one employer simultaneously. To reconcile the difference, when observing an instance of multiple job

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[13]For a number of immigrant respondents, the reported age at immigration is lower than the typical age of the reported completed schooling level. For example, immigrants reporting a college degree who migrated at age 18 likely obtained their degrees in Canada.

[14]See, for example, Skuterud and Su (2012) and Ferrer and Riddell (2008).

[15]There is a survey question asking respondents where they did most of their elementary and high-school education. However, no such information is available for post-secondary schooling.

holding, we assume that the spell that started later did not begin until the one that started earlier ended, and adjust the starting date of the latter job accordingly. This treatment of multiple job-holding is common in the literature.[16]

When a job spell is completed, the type of transition made at the end of the spell is based on how long it takes the worker to start a new job. We determine that an individual makes a job-to-job transition if the gap between two jobs is less than 14 days. Otherwise, the gap is treated as an unemployment spell and the transition is recorded as a job-to-unemployment transition.

Wage information is converted into monthly terms based on the reported unit of pay, and converted into real terms with year 2002 as the base year. In order to exclude extreme observations, we trimmed the top 3% and bottom 2% of the earnings distribution.[17]

The above steps yield the final estimation sample of size 3877, with 228 immigrant observations. Of the constructed labour market histories during the survey, the following set of information is used to calculate the likelihood contributions. The first pieces of information that enter into the likelihood are the employment status and residual duration of the first spell. If it is a job spell, the wage earned on the job and, if applicable, the type of transition made at the end of the spell are also included in the likelihood. If the initial spell is a complete unemployment spell, the characteristics of the following job spell enter into the likelihood as well. If the initial spell is a complete job spell, the duration of the next spell is also included in the likelihood but only if it is an unemployment spell.

Table 1 shows the sample statistics from the estimation sample.[18] Row 2 shows that the fractions of individuals who were initially unemployed were 0.053 for natives and 0.134 for immigrants, yielding a gap of 0.081. In addition to a higher unemployment rate, immigrants also have a longer mean unemployment duration than natives. The mean job durations are about 36 months and 30 months for natives and immigrants, respectively, and job spells exhibit high censoring rates for both groups.[19] While two fifths of the completed job spells ended with transitions to a new job for

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[16]See, for example, Bowlus et al. (2001).

[17]Trimming is standard in this literature to avoid estimates of reservation wages that are too small and productivity estimates that are too large. See Bowlus et al. (2001).

[18]As noted above the reported statistics are weighted by the 2002 cross-section sample weights.

[19]When reading the values reported in rows 3 to 7, it is important to keep in mind that spells may be censored at different dates for two reasons. First, the estimation sample is from unbalanced panel data. Second, the second spell inevitably has a shorter sample window than the first spell.

Table 1: Summary Statistics from the Estimation Sample

		Natives	Immigrants
1	Number of observation	3649	228
2	Fraction of individuals initially unemployed	0.053	0.134
3	Mean unemployment duration (in month)	5.06	6.84
4	Fraction of censored spells among unemployment spells	0.15	0.07
5	Mean job duration (in month)	35.59	30.21
6	Fraction of censored spells among job spells	0.75	0.70
7	Fraction of completed job spells ending with a job-to-job transition	0.40	0.23
8	Mean monthly earnings	4021.24	3510.50
9	Mean monthly wage accepted out of unemployment	2907.32	2463.59

natives, the corresponding number for immigrants was less than a quarter.

The descriptive statistics suggest that immigrants are facing different search frictions with longer unemployment durations and lower job-to-job transition rates. Immigrants also have much higher unemployment rates and shorter job durations. Differences in job offer arrival rates alone may readily account for higher unemployment rates, but may have more difficulty in simultaneously explaining the lower job-to-job transition rates. Immigrants may also be facing higher job destruction rates. Therefore, in what follows, we also estimate a model specification that allows for different job destruction rates for the two groups.[20] This improves the model fit substantially.

There is a sizable gap in monthly earnings between the two groups. As shown in row 8, the mean monthly earnings for immigrant was $3510.50 as opposed to $4021.24 for natives, yielding roughly a $500 earnings gap. Consistent with the job search model with on-the-job search, the mean monthly earnings out of unemployment is lower than the mean monthly earnings for both groups. There is a $443.73 earnings gap in the mean accepted earnings level between natives and immigrants.

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[20]The job destruction rate is not allowed to change when immigrants assimilate in the model. That is, the job offer arrival rates change but immigrants continue to face a higher job destruction rate. This is partly done to match the observed data, but also for simplicity in solving the equilibrium wage offer distribution. In addition, it is not clear that changes in the job destruction process should be part of assimilation due to learning about how to search more effectively.

This gap is quite large and is incompatible with the modeling assumptions that natives and immigrants face the same offer distribution and accept all offers. However, the standard deviations (134.14 and 259.32 for natives and immigrants, respectively) are rather large because of the small numbers of observations.

4   Estimation Results

4.1   Parameter Estimates

We follow Bowlus et al. (2001) in determining the number of firm types Q. Their method yields $Q = 7$ for our estimation sample. Levels beyond seven yielded no further improvements in the likelihood and productivity parameter estimates that were substantially higher at the top. In addition, the estimated search parameters were stable once the number of firm type was increased to this level.

The estimation results are presented in Tables 2, 3 and 4. Table 2 presents the estimated values for the search parameters. The first column shows the estimation results with both natives and immigrants facing a common job destruction rate, and the second column shows the estimation results with natives and immigrants facing job destruction rates of δ_1 and δ_1^m, respectively. The parameter estimates reveal a large difference between δ_1 and δ_1^m, though δ_1^m is not precisely estimated. Allowing the job destruction rates to differ between the two groups results in an improvement in the log-likelihood value and fits the observed duration and transition data better. In the following discussion, therefore, we focus on the parameter estimates with separate job destruction rates.[21]

The estimate for λ_0 shows that receiving a job offer is a fairly frequent event for native workers during unemployment with an implied mean unemployment duration of 6.4 months. In contrast, the job offer arrival rate while employed and job destruction rate are estimated to be very low for natives. The ratio of λ_1 and δ_1 gives a measure of the expected number of job offers during an employment spell and is often used

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[21]Once we allow for different job destruction rates for the two groups, the propositions stated in Section 2 need to be modified because they rely on the assumption of common job destruction rate. However, if $\delta_1 < \delta_1^m$, the result presented in Proposition 3 remains intact and the earnings distribution of natives first-order stochastically dominates the one for immigrants. In contrast, in Proposition 4 $G_n(w, a)$ and $G_m(w, a)$ will have different limits with respect to a. As a result, earnings convergence will be reduced such that the limit of $G_n(w, a)$ will still first-order stochastically dominate the one for $G_m(w, a)$.

Table 2: Parameter Estimates: Event Arrival Rates

Parameter	Common job destruction rate	Separate job destruction rates
δ_2^*	0.0024	0.0024
μ^*	0.2120	0.2120
λ_0	0.1556	0.1546
	(0.0094)	(0.0094)
λ_1	0.0089	0.0086
	(0.0010)	(0.0010)
δ_1	0.0047	0.0044
	(0.0003)	(0.0003)
δ_1^m		0.0075
		(0.0017)
α_0	0.6288	0.6471
	(0.1927)	(0.2100)
α_1	0.0735	0.0702
	(0.1146)	(0.1453)
η	0.0055	0.0064
	(0.0008)	(0.0010)
Log-likelihood	-37402.59	-37391.24

Note: Bootstrap standard errors are presented
in parentheses.
* Values assigned outside estimation

as a measure of search frictions. It is also a measure of how much earnings growth
the model will generate as individuals move up the job ladder through on-the-job
search. For the natives, this ratio is 1.98, which is higher than the value found for
Canada in Bowlus (1998), but by international comparisons is relatively low.[22] Given
the relatively low unemployment rate and high censoring rate of job spells observed
in data, these low values can be expected.[23]

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[22]The fact that our ratio is higher than that in Bowlus (1998) is not surprising given our estimation
sample contains more educated Canadians. However, in both cases the ratio for Canada is low
compared to other countries. For example, the value estimated for U.S. males with educational
attainment comparable to those in our analysis sample ranges from 1.75 to 4.62 (Bowlus and Seitz
(2000) and Flinn (2002)).

[23]In order to examine the effect of the high job censoring rate on the parameter estimates, we
estimated the model restricting the native worker sample to age 20 to 35, which had a lower job
censoring rate than the original sample. We also attempted a different estimation strategy, used in

Table 3: Parameter Estimates: Wage Cuts

Parameter	Common job destruction rate	Separate job destruction rates
w_{min}	1315.80	1315.80
	(3.19)	(2.92)
w_{H1}	2580.00	2580.00
	(433.26)	(452.36)
w_{H2}	3440.00	3440.00
	(479.38)	(473.70)
w_{H3}	4000.00	4000.00
	(425.22)	(436.20)
w_{H4}	4733.44	4733.44
	(500.63)	(525.96)
w_{H5}	5000.00	5000.00
	(585.64)	(637.88)
w_{H6}	5825.00	5825.00
	(759.34)	(793.43)
w_{H7}	8520.79	8520.79
	(0.82)	(0.82)

Note: Bootstrap standard errors are presented in parentheses.

Although not precisely estimated, the point estimates for α_0 and α_1 reveal differences in the job search process between natives and newly-arrived immigrants. The estimates for α_0 and λ_0 together imply that the job offer arrival rate for immigrants is 0.1002 giving an unemployment duration of 10.0 months for type 1 immigrants. The estimate for α_1 implies that the job offer arrival rate for employed type 1 immigrants is less than one tenth the native job offer arrival rate on-the-job and one tenth their own job destruction rate. All of this suggests that type 1 immigrants face substantial search frictions while employed and are, therefore, much more likely to have their jobs end with transitions to unemployment than are natives. Once immigrants acquire the same search parameters as natives, their job offer arrival rate while employed slightly exceeds their job destruction rate giving a ratio of 1.17.

Bowlus and Seitz (2000), that omits job duration data and relies on the initial unemployment rates and the transition data at the end of job spells to identify λ_1 and δ_1. Although unreported here, in both cases, the estimates yielded higher values not only for λ_1 but also for δ_1 resulting in ratios and earnings growth predictions that were hardly altered.

Table 4: Parameter Estimates: Firm Productivity Levels and Distribution

Parameter	Common job destruction rate	Separate job destruction rates	Parameter	Common job destruction rate	Separate job destruction rates
p_1	5100.91 (468.10)	5113.64 (496.40)	γ_1	0.3598 (0.1141)	0.3627 (0.1198)
p_2	5517.98 (545.92)	5533.66 (594.65)	γ_2	0.6026 (0.1146)	0.6057 (0.1121)
p_3	6384.91 (1031.13)	6440.80 (1161.29)	γ_3	0.7281 (0.0768)	0.7306 (0.0762)
p_4	7645.26 (1703.17)	7728.36 (1928.94)	γ_4	0.8462 (0.0572)	0.8478 (0.0573)
p_5	9070.35 (2716.80)	9188.67 (3292.69)	γ_5	0.8769 (0.0410)	0.8783 (0.0436)
p_6	11908.38 (5897.89)	12100.86 (6736.32)	γ_6	0.9354 (0.0260)	0.9362 (0.0267)
p_7	24989.68 (8838.72)	25553.25 (9672.67)	γ_7	1	1

Note: Bootstrap standard errors are presented in parentheses.

The estimate for η is 0.0064, which implies that it takes newly arrived immigrants 13 years to acquire the native search parameters. Interpreted slightly differently, 47% of a cohort of immigrants who immigrated 10 years previously have acquired native search parameters.

The finding that search assimilation for immigrants takes, on average, more than a decade is in line with some of the previous search assimilation findings. For example, based on their estimation results, Daneshvary et al. (1992) argue that immigrants reach "information parity" with natives after about 12 years since migration in the United States.[24] In contrast, based on their duration analysis of unemployment, Frijters et al. (2005) extrapolate that it takes immigrants more than 40 years to attain the same hazard rate out of unemployment as their native peers in Britain.

Studies taking a human capital approach to assimilation also often find that it takes immigrants decades to catch up with natives, though a common feature is a

[24]Their view is that the amount of information available to workers searching for jobs is related to the ratio between the actual and potential earnings where potential earnings means the upper support of the wage offer distribution. They found that this ratio was below natives' level for newly arrived immigrants, but it caught up to the same level after roughly 12 years since migration.

much faster initial rate of catch up. Skuterud and Su (2012), for example, report results for a sample of recent Canadian immigrants (arrival cohort 1990-2002). These were compared with similarly aged native workers. In their preferred specification the initial wage gap of 0.29 log points was more than halved after 8 years, declined further to year 13, but then remained roughly constant at 0.09 log points thereafter. Skuterud and Su argue that this pattern of strong decreasing relative returns to host country experience reflects what might be expected from "language acquisition or acculturation processes" (p.1124). However, our results indicate that search assimilation may be responsible for much of this convergence and that more conventional human capital models may overestimate the role of human capital assimilation in not taking into account search assimilation.

Tables 3 and 4 show the estimates related to the firm productivity distribution and the resulting wage cuts. The productivity distribution is right skewed with the lowest two levels accounting for the majority of the productivity distribution. The implied average monthly productivity level is \$7526.56. The large values for the highest productivity levels, needed to meet the equal-profit condition at the upper end of the wage distribution, are a common outcome of this model.

4.2   Model Fit

We examine how well the model fits the observed data by comparing the summary statistics reported in Table 1 with model predictions. When predicting the moments of the duration and transition data, it is important to account for the fact that our estimation sample is unbalanced panel data and spells can be censored at different dates. To control for this issue we simulate a sample of a large number of job histories matching the survey response outcomes in the estimation sample. One exception to this is that the predicted values for the earnings outcomes given in row 8 are obtained by numerically calculating the mean of the offer distribution rather than from the simulations. The results are presented in Table 5.

The model matches the duration and transition data of natives and immigrants well overall. It underpredicts the unemployment rates for both groups, and somewhat overpredicts the unemployment durations. Unfortunately the model cannot match both of these moments since to match the first the job offer arrival rate while unemployed needs to be lower and to fix the second it needs to be higher.

Table 5: Predicted Moments from the Estimation Result with Separate Job Destruction Rates for Natives and Immigrants

		Natives		Immigrants	
		Observed	Predicted	Observed	Predicted
1	Fraction of individuals initially unemployed	0.053	0.042	0.134	0.072
2	Mean unemployment duration (in month)	5.06	5.83	6.84	7.37
3	Fraction of censored spells among all unemployment spells	0.15	0.10	0.07	0.14
4	Mean job duration (in month)	35.59	35.87	30.21	32.33
5	Fraction of censored spells among all job spells	0.75	0.74	0.70	0.69
6	Fraction of completed job spells ending with a job-to-job transition	0.40	0.41	0.23	0.20
7	Mean monthly earnings	4021.24	4063.54	3510.50	3676.74
8	Mean monthly wage accepted out of unemployment	2907.73	3341.87	2463.59	3341.87

Not surprisingly, as shown in Figure 1, the predicted distribution of natives' earnings fits the observed distribution very closely. The model produces an earnings gap between natives and immigrants of approximately \$390, which captures three quarters of the observed gap. The same figure shows that the predicted earnings distribution for immigrants lies slightly to the right of the observed distribution reflecting the unexplained portion of the observed earnings gap.

Row 8 of Table 5 shows that the model is having a difficult time fitting the offer distribution, substantially overpredicting it. The offer distribution is identified from earnings observations accepted out of unemployment and the number of such observations is modest in the data. Therefore, fitting the data in this dimension does not seem to have influenced the estimation substantially. The difficulty in capturing enough difference between the earnings and offer distributions reflects the estimated low value of λ_1/δ_1, and also points to the model's problem in generating sufficient earnings growth. This suggests that the model is missing important earnings growth mechanisms. The most obvious factor omitted by the model is human capital accumulation, and enriching the model in this direction is an interesting avenue for

Figure 1: Observed and Predicted Earnings Distributions for Natives and Immigrants
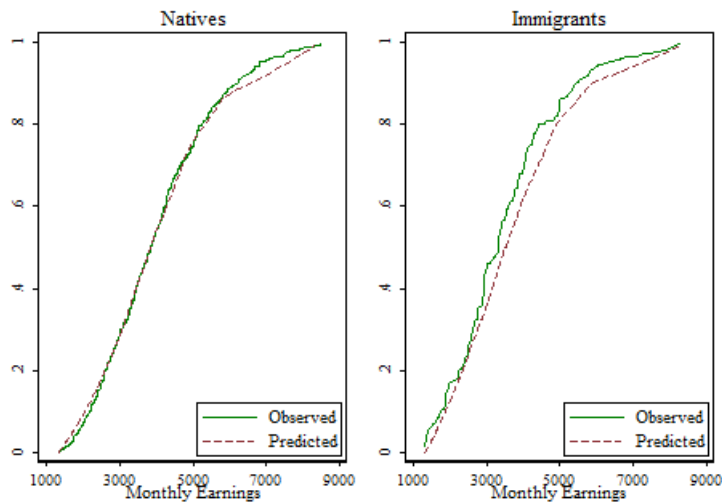
future work.[25] Finally, the observed gap in accepted wages out of unemployment between natives and immigrants may reflect productivity differences between the two groups. Therefore, it may be important to investigate whether there are separate labour markets for natives and immigrants.[26]

4.3   Implications of Estimation Results For Earnings Assimilation

The estimation results imply that it takes newly arrived immigrants, on average, 13 years to acquire the native search parameters. We examine the implications of this estimated job search assimilation process for immigrants' life cycle earnings growth. In Figure 2, the solid-lined curve shows the predicted mean monthly earnings profile of immigrants since migration, relative to the earnings level in the first year since migration. On average, immigrants are predicted to experience about 5% earnings growth in the first 10 years since migration, and about 18% earnings growth over 40 years since migration. The earnings profile is S-shaped, originally exhibiting slower

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[25]The addition of human capital can substantially complicate the equilibrium solution to the model.

[26]This difference may also be aggravated by our assumption of a common minimum wage.

Figure 2: Predicted Immigrants' Earnings Growth
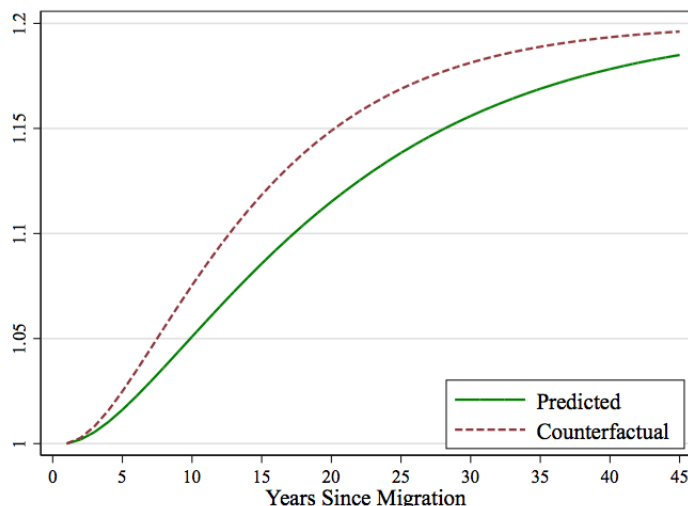
earnings growth because of the lower rates of job offer arrival when they are new to the host country.

Indeed, the estimates reveal that newly arrived immigrants search under a very low job offer arrival rate while employed. This limits their chances of finding better paying jobs. If immigrants could search as effectively as natives sooner, they would experience a faster earnings growth. The broken lined curve in the same figure shows a counterfactual scenario in which η is doubled to 0.0127, halving the average length of time needed to spend in the host country before acquiring the native job search efficiency. The counterfactual earnings profile shows faster and larger earnings growth, and produces 18% growth in 30 years since migration.

Figure 3 shows predicted earnings profiles of immigrants entering the host country at different ages. These profiles are measured relative to their native counterparts, with an assumption that native workers enter the labour market at age 20. The earnings are followed until immigrants reach age 65. For each age group, the initial earnings gap reflects the natives' advantage of having more time operating in the host country labour market. For any age group in Figure 3, the relative earnings decline initially for two reasons. First, newly arrived immigrants search with lower job search efficiency. Second, natives are experiencing robust earnings growth during their early years in the labour market. As immigrants age, their earnings level converges to a

Figure 3: Predicted Immigrant Earnings Relative to Native Earnings
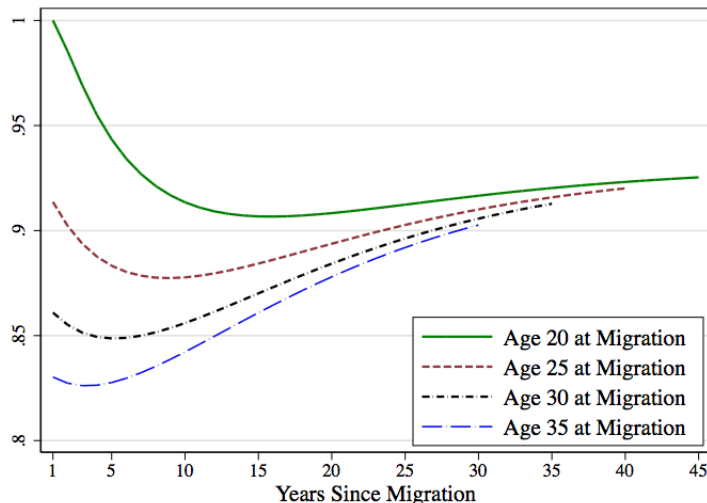
level about 8% below the native earnings, failing to achieve the earnings parity. This failure of earnings convergence is because of the immigrants' higher job destruction rate. The same exercise is conducted assuming that immigrants face the native job destruction rate, and this counterfactual experiment produces the relative earnings profile in Figure 4. In this counterfactual scenario, immigrants close the earnings gap more than in the previous case. However, even as they turn 65 they have yet to achieve earnings parity.

It is also interesting to ask how natives are affected by having to compete with immigrants in the same labour market. The presence of new immigrants produces an equilibrium effect, which reflects a change in firms' wage posting strategies. They search at lower job offer arrival rates, resulting in an increase in the fraction of workers with less propensity to make a job-to-job transition. This leads to an increase in firms' monopsony power in the model, allowing them to post lower wages and shift the offer distribution to the left in equilibrium.[27] Without immigrants, the firms' monopsony power would be reduced, and the equilibrium wage offer distribution would shift to the right.[28] To look at this effect on natives' earnings, we solve the equilibrium with

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[27]See Burdett and Mortensen (1998) for a discussion on how workers' likelihood to make a job-to-job transition as opposed to a job-to-unemployment transition affects the monopsony power of firms.

[28]We do not account for the effect of the immigrant labour force on native job offer arrival rates

Figure 4: Counterfactual Immigrant Earnings Relative to Native Earnings
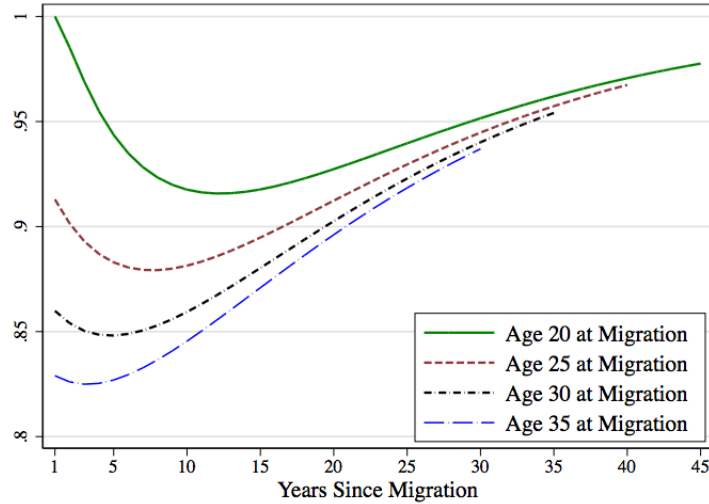
$\mu = 0$, and compare the native earnings distribution under this equilibrium with the one under the estimated parameters. These distributions are presented in Figure 5. The mean difference in these two distributions are $175.88, implying a 4% reduction in the mean earnings of natives due to the presence of immigrants in the labour market.

5   Concluding Remarks

Immigrant assimilation is a major issue in many countries. There is a very large literature that studies assimilation primarily through a human capital framework. While a variety of these studies, going back to Chiswick (1978), refers to immigrants accumulating host country specific knowledge as well as skills following migration, the accumulation of knowledge of how the host country labour market works and how to search efficiently has received relatively little attention. In this paper, we use a search model to study assimilation via this potentially important host-country specific knowledge. Specifically, we present and estimate an equilibrium search model of immigrants operating in the same labour market as natives using Canadian panel data.

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and any resulting equilibrium effects.

Figure 5: Predicted Native Earnings Distributions
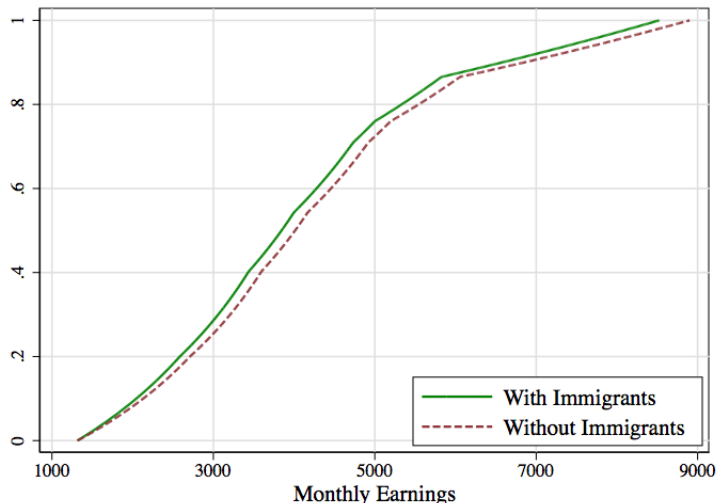
Assimilation via acquisition of knowledge of how the host country labour market works and how to search efficiently in it takes place in the model by having immigrants initially face a (potentially) lower arrival rate of job offers, and allowing them to acquire the same job offer arrival rate according to a stochastic process. The estimation results show substantial differences in job offer arrival rates between natives and newly arrived immigrants, as well as a difference in the job destruction rate between natives and immigrants. These differences are able to account for three quarters of the observed earnings differential between natives and immigrants. The results also imply that it takes immigrants, on average, 13 years to acquire the same search parameters as natives. The job search assimilation process generates 18% earnings growth for immigrants in 40 years since migration. The parameter estimates reveal that newly arrived immigrants have a hard time generating earnings growth because of their very low job offer arrival rate while employed. If the time needed to acquire the native job search process were halved, the same 18% earnings growth would be achieved 10 years sooner than the estimates predict. This has important implications for policy initiatives to encourage immigrant assimilation.

Although the model is able to fit various dimensions of the observed data well, it is at odds with the observed data in some dimensions. Particularly, the model is not able to capture the difference in accepted wages out of unemployment between

natives and immigrants and it has difficulty generating sufficient earnings growth. These two findings may point to productivity differences and the role of human capital accumulation, and enriching the model in this dimension is an interesting avenue for future research. In particular, given the large previous literature emphasizing the role of human capital accumulation in immigrant assimilation, it is important to understand the relative roles of human capital and search in this process.

Finally, given the modest number of immigrant observations in the estimation sample, the estimates pertaining to the immigrant job search parameters are not precisely estimated. In addition, it was not possible to allow for initial job offer arrival rates to depend on potentially relevant factors, such as the degree of similarity between the labour markets in the source and host countries. An important next step is to incorporate heterogeneity in initial Canadian Labour market knowledge through the use of alternative data sources such as the LSIC.

Appendix A   Proofs of Propositions

Proof of Proposition 1

Accounting for the reservation wage property of type 1 immigrant worker's problem, equation (4) can be rewritten as

$$rV_m^u = b + \alpha_0\lambda_0 \int_{R_m}^{\overline{w}} \left(V_m^e(x) - V_m^u\right)dF(x) + \eta\left(V_n^u - V_m^u\right) - \delta_2 V_m^u.$$

Analogously equation (5) can be rewritten as

$$rV_m^e(w) = w + \alpha_1\lambda_1 \int_{w}^{\overline{w}} \left(V_m^e(x) - V_m^e(w)\right)dF(x) + \eta I(w \geq R_n)\left(V_n^e(w) - V_m^e(w)\right)$$
$$+ \eta I(w < R_n)\left(V_n^u - V_m^e(w)\right) + \delta_1\left(V_m^u - V_m^e(w)\right) - \delta_2 V_m^e(w).$$

The above equation yields

$$\frac{d}{dw}V_m^e(w) = \frac{1 + \eta I(w > R_n)\frac{d}{dw}V_n^e(w)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)} \tag{12}$$

where $V_m^e(w)$ is differentiable.[29] Equation (2) yields

$$\frac{d}{dw}V_n^e(w) = \frac{1}{\rho + \lambda_1\overline{F}(w)}. \tag{13}$$

These two equations, together with $V_m^e(R_m) = V_m^u$ and $V_n^e(R_n) = V_n^e$, yield

$$
\begin{aligned}
R_m =& b + (\alpha_0\lambda_0 - \alpha_1\lambda_1)\int_{R_m}^{\overline{w}}\big(V_m^e(x) - V_m^e(R_m)\big)dF(x) + \eta I(R_m > R_n)\big(V_n^e(R_n) - V_n^e(R_m)\big) \\
=& b + (\alpha_0\lambda_0 - \alpha_1\lambda_1)\int_{R_m}^{\overline{w}}\overline{F}(x)\frac{d}{dw}V_m^e(x)dx + \eta I(R_m > R_n)\int_{R_m}^{R_n}\frac{d}{dw}V_n^e(x)dx,
\end{aligned}
\tag{14}
$$

where the second term is obtained by integration by parts.

Using equation (12), the integral in the second term on the right-hand side of equation (14) is given by

$$
\begin{aligned}
\int_{R_m}^{\overline{w}}\overline{F}(x)\frac{d}{dw}V_m^e(x)dx =& \int_{R_m}^{\overline{w}}\frac{\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx \\
&+ I(R_m < R_n)\int_{R_n}^{\overline{w}}\frac{\eta\overline{F}(x)\frac{d}{dw}V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx + I(R_m \geq R_n)\int_{R_m}^{\overline{w}}\frac{\eta\overline{F}(x)\frac{d}{dw}V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx. \quad (15)
\end{aligned}
$$

The integral in the third term on the right-hand side of equation (15) can be split into two terms as follows:

$$
\int_{R_m}^{\overline{w}}\frac{\eta\overline{F}(x)\frac{d}{dw}V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} = \int_{R_n}^{\overline{w}}\frac{\eta\overline{F}(x)\frac{d}{dw}V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx - \int_{R_n}^{R_m}\frac{\eta\overline{F}(x)\frac{d}{dw}V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx.
$$

Thus equation (15) can be rearranged to

$$
\begin{aligned}
\int_{R_m}^{\overline{w}}\overline{F}(x)V_m^e(x)dx =& \int_{R_m}^{\overline{w}}\frac{\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx + \int_{R_n}^{\overline{w}}\frac{\eta\overline{F}(x)V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx \\
&- I(R_m \geq R_n)\int_{R_n}^{R_m}\frac{\eta\overline{F}(x)V_n^e(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx
\end{aligned}
$$

Then substituting the above expression into equation (14) and a few algebraic steps yield the desired result. $\qquad\square$

---

[29]From equation (5), it is clear that $V_m^e(w)$ has a kink at R_n.

Proof of Lemma 1

Define function $H(w)$ by

$$H(w) = b - w + \int_w^{\bar{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)}dx + \int_{R_n}^{\bar{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx$$
$$- I(w > R_n)\int_{R_n}^w \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx. \quad (16)$$

By Proposition 1, R_m solves equation $H(R_m) = 0$. Function $H(w)$ can be rewritten as

$$H(w) = b - \bar{w} + \int_w^{\bar{w}} \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx + \int_{R_n}^{\bar{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx$$
$$- I(w > R_n)\int_{R_n}^w \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx. \quad (17)$$

Note that $H(w)$ is continuous. It is also decreasing because

$$H'(w) = -\frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(w)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)} < 0$$

for $w < R_n$, and

$$H'(w) = -\frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(w)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)} - \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(w)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(w)} \frac{\eta}{\rho + \lambda_1\overline{F}(w)} < 0$$

for $w > R_n$. Therefore $R_n > R_m$ if and only if $H(R_n) < H(R_m) = 0$.

Evaluate $H(w)$ at R_n:

$$H(R_n) = b - \bar{w} + \int_{R_n}^{\bar{w}} \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)}dx + \int_{R_n}^{\bar{w}} \frac{(\alpha_0\lambda_0 - \alpha_1\lambda_1)\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx$$
$$= b - \bar{w} + \int_{R_n}^{\bar{w}} \frac{\rho + \eta + \alpha_0\lambda_0\overline{F}(x)}{\rho + \eta + \alpha_1\lambda_1\overline{F}(x)} \frac{\eta + \rho + \lambda_1\overline{F}(x)}{\rho + \lambda_1\overline{F}(x)}dx - \int_{R_n}^{\bar{w}} \frac{\eta}{\rho + \lambda_1\overline{F}(x)}dx. \quad (18)$$

Now equation (3) can be rewritten as

$$b - \overline{w} = -\int_{R_n}^{\bar{w}} \frac{\rho + \lambda_0\overline{F}(w)}{\rho + \lambda_1\overline{F}(x)}dx. \quad (19)$$

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Substituting equation (19) into equation (18) yields

$$H(R_n) = \int_{R_n}^{\bar{w}} \frac{\rho + \eta + \alpha_0 \lambda_0 \overline{F}(x)}{\rho + \eta + \alpha_1 \lambda_1 \overline{F}(x)} \frac{\eta + \rho + \lambda_1 \overline{F}(x)}{\rho + \lambda_1 \overline{F}(x)} dx - \int_{R_n}^{\bar{w}} \frac{\eta + \rho + \lambda_0 \overline{F}(x)}{\rho + \lambda_1 \overline{F}(x)} dx.$$

Hence $R_n > R_m$ if and only if

$$\int_{R_n}^{\bar{w}} \left[\frac{\eta + \rho + \lambda_0 \overline{F}(x)}{\rho + \lambda_1 \overline{F}(x)} - \frac{\rho + \eta + \alpha_0 \lambda_0 \overline{F}(x)}{\rho + \eta + \alpha_1 \lambda_1 \overline{F}(x)} \frac{\eta + \rho + \lambda_1 \overline{F}(x)}{\rho + \lambda_1 \overline{F}(x)} \right] dx > 0,$$

which is the desired result. □

Proof of Proposition 2

Given $\alpha_1 < 1$ and $\eta > 0$, using equations (8) and (9), we can show that

$$G_{m1}(w) = \frac{F(w)}{1 + \frac{\alpha_1 \lambda_1}{\delta + \eta} \overline{F}(w)} > \frac{F(w)}{1 + \frac{\lambda_1}{\delta + \eta} \overline{F}(w)} > \frac{F(w)}{1 + \frac{\lambda_1}{\delta} \overline{F}(w)} = G_n(w),$$

which yields $G_{m1}(w) > G_n(w)$ for any $w \in [\underline{w}, \overline{w}]$. This establishes the first-order stochastic dominance of $G_n(w)$ over $G_{m1}(w)$.

Next, using equations (8) and (10), we can show that

$$G_{m2}(w) = \left(1 - \frac{\delta_2 \alpha_0 (\delta + \lambda_0) \alpha_1 \lambda_1 \overline{F}(w)}{\delta(\alpha_0 \delta_2 + \alpha_0 \lambda_0 + \delta + \eta)(\delta + \eta + \alpha_1 \lambda_1 \overline{F}(w))} \right) G_n(w). \tag{20}$$

It is straightforward to show

$$0 \leq \frac{\delta_2 \alpha_0 (\delta + \lambda_0) \alpha_1 \lambda_1 \overline{F}(w)}{\delta(\alpha_0 \delta_2 + \alpha_0 \lambda_0 + \delta + \eta)(\delta + \eta + \alpha_1 \lambda_1 \overline{F}(w))} < 1,$$

which yields $G_{m2}(w) < G_n(w)$ for any $w \in [\underline{w}, \overline{w}]$. This establishes the first-order stochastic dominance of $G_{m2}(w)$ over $G_n(w)$. □

Proof of Proposition 3

$G_m(w)$ is given by

$$G_m(w) = \frac{E_{m1} G_{m1}(w) + E_{m2} G_{m2}(w)}{E_{m1} + E_{m2}} \tag{21}$$

where E_{m1} and E_{m2} denote the steady-state measures of employed type 1 and type 2 immigrants, respectively. These two variables are determined by the following steady-state flow analysis.

First, define U_{m1} and U_{m2} as the steady-state measures of unemployed type 1 and type 2 immigrants, respectively. Then, E_{m1}, E_{m2}, U_{m1}, and U_{m2} sum up to the measure of all immigrant workers:

$$U_{m1} + U_{m2} + E_{m1} + E_{m2} = \mu. \tag{22}$$

Second, type 1 immigrants leave employment at rate δ_1 due to job separation, and at rate δ_2 due to permanent exit from the labour market. They may become type 2 immigrants at rate η. This outflow is balanced by the inflow of unemployed type 1 immigrants becoming employed at rate $\alpha_0 \lambda_0$. Therefore,

$$(\delta_1 + \delta_2 + \eta)E_{m1} = \alpha_0 \lambda_0 U_{m1}. \tag{23}$$

Third, type 2 immigrants leave unemployment at rate λ_0, and leave the labour market permanently at rate δ_2. This outflow is balanced by type 1 unemployed immigrants becoming type 2 at rate η, and type 2 employed immigrants becoming unemployed at rate δ_1. Therefore,

$$(\lambda_0 + \delta_2)U_{m2} = \eta U_{m1} + \delta_1 E_{m2}. \tag{24}$$

Fourth, employed type 2 immigrants become unemployed at rate δ_1, or leave the labour market permanently at rate δ_2. This outflow is balanced by the inflow of unemployed type 2 immigrants becoming employed at rate λ_0 and type 1 immigrants becoming type 2 immigrants. Therefore,

$$(\delta_1 + \delta_2)E_{m2} = \lambda_0 U_{m2} + \eta E_{m1}. \tag{25}$$

Solving equations (22) - (25), we obtain E_{m1} and E_{m2}, respectively, as

$$E_{m1} = \frac{\delta_2 \alpha_0 \lambda_0}{(\eta + \delta_2)(\alpha_0 \lambda_0 + \eta + \delta)}\mu, \tag{26}$$

and

$$E_{m2} = \frac{\eta \lambda_0 (\delta + \eta + \alpha_0 \lambda_0 + \alpha_0 \delta_2)}{(\eta + \delta_2)(\delta + \lambda_0)(\alpha_0 \lambda_0 + \eta + \delta)}\mu. \tag{27}$$

Substituting equations (9), (10), (26), and (27) into equation (21) to obtain the expression for $G_m(w)$, and then comparing the result with $G_n(w)$ in equation (8) yields the following relationship between $G_m(w)$ and $G_n(w)$:

$$G_m(w) = \left(1 + \frac{\delta_2(\delta + \lambda_0)(\delta + \eta)\alpha_0\lambda_0(1 - \alpha_1)\lambda_1\overline{F}(w)}{\delta\big((\delta + \eta + \lambda_0)(\lambda_0\delta_2\alpha_0 + \eta\lambda_0(\delta + \eta + \alpha_0\lambda_0))(\delta + \eta + \lambda_1\overline{F}(w))\big)}\right)G_n(w).$$

Since $\alpha_1 < 1$, then

$$\frac{\delta_2(\delta + \lambda_0)(\delta + \eta)\alpha_0\lambda_0(1 - \alpha_1)\lambda_1\overline{F}(w)}{\delta\big((\delta + \eta + \lambda_0)(\lambda_0\delta_2\alpha_0 + \eta\lambda_0(\delta + \eta + \alpha_0\lambda_0))(\delta + \eta + \lambda_1\overline{F}(w))\big)} > 0,$$

which yields

$$G_m(w) > G_n(w)$$

for any $w \in [\underline{w}, \overline{w}]$. Thus, $G_n(w)$ first-order stochastically dominates $G_m(w)$. $\qquad\square$

Proof of Proposition 4

In order to establish Proposition 4, we solve a number of differential equations. The outline of this proof is as follows. First, we show the limit of $G_n(w, a)$. Then we do the same for $G_m(w, a)$, and show that it has the same limit.

Step 1

Let $E_n(a)$ and $U_n(a)$ denote the mass of natives of age a who are employed and unemployed, respectively. At any given time, employed workers become unemployed at rate δ_1 and leave the labour market at rate δ_2, and unemployed workers become employed at rate λ_0, and leave the labour market at rate δ_2. Moreover, due to the steady-state assumption, all cohorts have identical aggregate employment and unemployment profiles at all ages. Exploiting the steady-state assumption, $U_n(a)$ and $E_n(a)$ are given by the following system of differential equations

$$\dot{U}_n(a) = -(\lambda_0 + \delta_2)U_n(a) + \delta_1 E_n(a)$$
$$\dot{E}_n(a) = \lambda_0 U_n(a) - (\delta_1 + \delta_2)E_n(a).$$

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Furthermore, all workers enter the labour market initially unemployed, implying $E_n(0) = 0$, while the aggregate condition yields $\int (U_n(a) + E_n(a))da = 1 - \mu$. Together with these conditions, the system of the these differential equations yields

$$U_n(a) = \left[\frac{\delta_1 \delta_2}{\lambda_0 + \delta_1} e^{-\delta_2 a} + \frac{\lambda_0 \delta_2}{\lambda_0 + \delta_1} e^{-(\lambda_0 + \delta_1 + \delta_2)a} \right] (1 - \mu), \tag{28}$$

$$E_n(a) = \left[\frac{\lambda_0 \delta_2}{\lambda_0 + \delta_1} e^{-\delta_2 a} - \frac{\lambda_0 \delta_2}{\lambda_0 + \delta_1} e^{-(\lambda_0 + \delta_1 + \delta_2)a} \right] (1 - \mu). \tag{29}$$

Let $M_n(w, a)$ be the steady-state stock of natives of age a earning wage w or less. Clearly $M_n(w, 0) = 0$. Job-to-job transitions and unemployment-to-job transitions produce the following differential equation regarding $M_n(w, a)$:

$$\frac{dM_n(w, a)}{da} = -(\delta_1 + \delta_2 + \lambda_1 \overline{F}(w))M_n(w, a) + \lambda_0 F(w)U_n(a).$$

The differential equation shows that the change in $M_n(w, a)$ with respect to a consists of two parts. The first part is the outflow from $M_n(w, a)$ due to on-the-job search, job destruction and permanent exit from the labour market. The second part is the inflow of unemployed natives finding wage offers of w or less. The general solution to this differential equation is given by

$$M_n(w, a) = e^{-(\delta + \lambda_1 \overline{F}(w))a} \left[\int [e^{(\delta + \lambda_1 \overline{F}(w))a} \lambda_0 F(w)U_n(a)]da + C \right] \tag{30}$$

where C is a constant to be determined by the condition $M_n(w, 0) = 0$. Together with equation (28), equation (30) gives

$$M_n(w, a) = (1 - \mu)\lambda_0 F(w) \left[\frac{\delta_1 \delta_2}{\lambda_0 + \delta_1} \frac{e^{-\delta_2 a}}{\delta_1 + \lambda_1 \overline{F}(w)} - \frac{\lambda_0 \delta_2}{\lambda_0 + \delta_1} \frac{e^{-(\lambda_0 + \delta)a}}{\lambda_0 - \lambda_1 \overline{F}(w)} \right] \\ + e^{-(\delta + \lambda_1 \overline{F}(w))a}C. \tag{31}$$

After pinning down C by the condition $M_n(w, 0) = 0$, equation (31) can be rewritten

as

$$M_n(w, a) = (1 - \mu)\lambda_0 F(w) \left[\frac{\delta_1 \delta_2}{\lambda_0 + \delta_1} \frac{e^{-\delta_2 a} - e^{-(\delta + \lambda_1 \overline{F}(w))a}}{\delta_1 + \lambda_1 \overline{F}(w)} \right.$$
$$\left. - \frac{\lambda_0 \delta_2}{\lambda_0 + \delta_1} \frac{e^{-(\lambda_0 + \delta)a} - e^{-(\delta + \lambda_1 \overline{F}(w))a}}{\lambda_0 - \lambda_1 \overline{F}(w)} \right]. \quad (32)$$

The age-dependent earnings distribution of natives, given by $G_n(w, a)$, is

$$G_n(w, a) = \frac{M_n(w, a)}{E_n(a)}.$$

Using equation (29) and (32), we obtain

$$G_n(w, a) = \frac{\delta_1 F(w)}{\lambda_1 \overline{F}(w) + \delta_1} \frac{1 - e^{-(\lambda_1 \overline{F}(w) + \delta_1)a}}{1 - e^{-(\lambda_0 + \delta_1)a}}$$
$$+ \frac{\lambda_0 F(w)}{\lambda_0 - \lambda_1 \overline{F}(w)} \frac{e^{-(\lambda_1 \overline{F}(w) + \delta_1)a} - e^{-(\lambda_0 + \delta_1)a}}{1 - e^{-(\lambda_0 + \delta_1)a}},$$

and therefore

$$\lim_{a \to \infty} G_n(w, a) = \frac{\delta_1 F(w)}{\delta_1 + \lambda_1 \overline{F}(w)}.$$

Step 2

The age profile of the earnings distribution of immigrants can be derived similarly. Let $M_{my}(w, a)$ be the steady-state stock of type y immigrants of age a earning wage w or less. For type 1 immigrants, the change in $M_{m1}(w, a)$ with respect to a comes from the outflow of workers due to job destruction, permanent exit, on-the-job search and type change, and the inflow of unemployed workers accepting wage w or less:

$$\frac{dM_{m1}(w, a)}{da} = -(\delta_1 + \delta_2 + \eta + \alpha_1 \lambda_1 \overline{F}(w))M_{m1}(w, a) + \alpha_0 \lambda_0 F(w)U_{m1}(a). \quad (33)$$

The above differential equation can be solved with the condition $M_{m1}(w, a) = 0$. For type 2 immigrants, the change in $M_{m2}(w, a)$ with respect to a comes from the outflow of workers due to job destruction, permanent exit and on-the-job search, the inflow from the pool of employed type 1 immigrants due to type change, and the inflow of

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unemployed workers accepting wage w or less:

$$\frac{dM_{m2}(w,a)}{da} = -(\delta_1 + \delta_2 + \lambda_1\overline{F}(w))M_{m2}(w,a) + \eta M_{m1}(w,a) + \lambda_0 F(w)U_{m2}(a). \quad (34)$$

The above differential equation can be solved with the condition $M_{m2}(w,a) = 0$.

The evolution of unemployment and employment measures of immigrants by age is given by

$$\begin{bmatrix} \dot{U}_{m1}(a) \\ \dot{E}_{m1}(a) \\ \dot{U}_{m2}(a) \\ \dot{E}_{m2}(a) \end{bmatrix} = \begin{bmatrix} -(\alpha_0\lambda_0 + \eta + \delta_2) & \delta_1 & 0 & 0 \\ \alpha_0\lambda_0 & -(\eta+\delta) & 0 & 0 \\ \eta & 0 & -(\lambda_0+\delta_2) & \delta_1 \\ 0 & \eta & \lambda_0 & -\delta \end{bmatrix} \begin{bmatrix} U_{m1}(a) \\ E_{m1}(a) \\ U_{m2}(a) \\ E_{m2}(a) \end{bmatrix}$$

The system of differential equation has the solution

$$\begin{bmatrix} U_{m1}(a) \\ E_{m1}(a) \\ U_{m2}(a) \\ E_{m2}(a) \end{bmatrix} = \begin{bmatrix} 0 & 0 & \delta_1 & 1 \\ 0 & 0 & \alpha_0\lambda_0 & -1 \\ \delta_1 & 1 & \frac{\delta_1(\delta_1+\alpha_0\lambda_0-\eta)}{\eta-\lambda_0-\delta_1} & -\frac{\eta}{\eta+(\alpha_0-1)\lambda_0} \\ \lambda_0 & -1 & \frac{(\delta_1+\alpha_0\lambda_0)\lambda_0-\alpha_0\lambda_0\eta}{\eta-\lambda_0-\delta_1} & \frac{\eta}{\eta+(\alpha_0-1)\lambda_0} \end{bmatrix} \begin{bmatrix} c_1 e^{-\delta_2 a} \\ c_2 e^{-(\lambda_0+\delta)a} \\ c_3 e^{-(\delta_2+\eta)a} \\ c_4 e^{-(\alpha_0\lambda_0+\eta+\delta)a} \end{bmatrix}$$

with constants c_1, c_2, c_3 and c_4 determined by the following conditions:

$$U_{m2}(0) = E_{m1}(0) = E_{m2}(0) = 0,$$

and

$$\int_0^\infty (U_{m1}(a) + U_{m2}(a) + E_{m1}(a) + E_{m2}(a))da = \mu.$$

These conditions yield

$$c_1 = \frac{\delta_2}{\delta_1 + \lambda_0}\mu, \quad c_3 = \frac{\delta_2}{\delta_1 + \alpha_0\lambda_0}\mu, \quad c_4 = \frac{\alpha_0\lambda_0\delta_2}{\delta_1 + \alpha_0\lambda_0}\mu,$$

and

$$c_2 = \frac{\eta\lambda_0(\alpha_0\lambda_0 + \delta_1)(\eta - \lambda_0 - \alpha_0\delta_1)}{(\lambda_0 + \delta_1)(\eta - \lambda_0 - \delta_1)(\eta + (\alpha_0 - 1)\lambda_0)}\mu.$$

The general solution to differential equation (33) is given by

$$M_{m1}(w,a) = e^{-(\alpha_1\lambda_1\overline{F}(w))a}\left[\alpha_0\lambda_0 F(w)\int\left[U_{m1}(a)e^{(\alpha_1\lambda_1\overline{F}(w)+\delta+\eta)a}\right]da + C\right]. \quad (35)$$

The integral on the right-hand side of equation (35) can be rearranged to

$$\int U_{m1}(a)e^{(\alpha_1\lambda_1\overline{F}(w)+\delta+\eta)a}da = \int\left[c_3\delta_1 e^{(\alpha_1\lambda_1\overline{F}(w)+\delta_1)a} + c_4 e^{(\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0)a}\right]da$$

$$= \frac{c_3\delta_1\, e^{(\alpha_1\lambda_1\overline{F}(w)+\delta_1)a}}{\alpha_1\lambda_1\overline{F}(w)+\delta_1} + \frac{c_4\, e^{(\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0)a}}{\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0}.$$

Therefore,

$$M_{m1}(w,a) = \alpha_0\lambda_0 F(w)\left[\frac{c_3\delta_1\, e^{-(\eta+\delta_2)a}}{\alpha_1\lambda_1\overline{F}(w)+\delta_1} + \frac{c_4\, e^{-(\eta+\delta_2)a}}{\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0}\right] + Ce^{-(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)a}. \quad (36)$$

Using $M_{m1}(w,0) = 0$ to solve for C, and substituting the result into equation (36) yields

$$M_{m1}(w,a) = \alpha_0\lambda_0 F(w)\left[c_3\delta_1\frac{e^{-(\eta+\delta_2)a} - e^{-(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)a}}{\alpha_1\lambda_1\overline{F}(w)+\delta_1}\right.$$

$$\left. +c_4\frac{e^{-(\eta+\delta_2)a} - e^{-(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)a}}{\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0}\right].$$

The general solution to equation (34) then yields

$$M_{m2}(w,a) = e^{-(\lambda_1\overline{F}(w)+\delta)a}\left[\int(\eta M_{m1}(w,a) + \lambda_0 F(w)U_{m2}(a))e^{(\lambda_1\overline{F}(w)+\delta)a}da + C_2\right]$$

$$= \eta e^{-(\lambda_1\overline{F}(w)+\delta)a}\int M_{m1}(w,a)e^{(\lambda_1\overline{F}(w)+\delta)a}da$$

$$+ \lambda_0 F(w)e^{-(\lambda_1\overline{F}(w)+\delta)a}\int U_{m2}(a))e^{(\lambda_1\overline{F}(w)+\delta)a}da + C_2 e^{-(\lambda_1\overline{F}(w)+\delta)a}. \quad (37)$$

The integrals on the right-hand side of equation (37) can be written as

$$
\int M_{m1}(w,a)e^{(\lambda_1\overline{F}(w)+\delta)a}da = \frac{\alpha_0\lambda_0 F(w)c_3\delta_1}{\alpha_1\lambda_1\overline{F}(w)+\delta_1}\left[\frac{e^{(\lambda_1\overline{F}(w)+\delta_1-\eta)a}}{\lambda_1\overline{F}(w)+\delta_1-\eta}-\frac{e^{((1-\alpha_1)\lambda_1\overline{F}(w)-\eta)a}}{(1-\alpha_1)\lambda_1\overline{F}(w)-\eta}\right]
$$
$$
+\frac{\alpha_0\lambda_0 F(w)c_4}{\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0}\left[\frac{e^{(\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta)a}}{\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta}-\frac{e^{((1-\alpha_1)\lambda_1\overline{F}(w)-\eta)a}}{(1-\alpha_1)\lambda_1\overline{F}(w)-\eta}\right],
$$

and

$$
\int U_{m2}(a)e^{\lambda_1\overline{F}(w)+\delta)a}da = c_1\delta_1\frac{e^{(\lambda_1\overline{F}(w)+\delta_1)a}}{\lambda_1\overline{F}(w)+\delta_1}+c_2\frac{e^{(\lambda_1\overline{F}(w)-\lambda_0)a}}{\lambda_1\overline{F}(w)-\lambda_0}
$$
$$
+c_3\frac{\delta_1(\delta_1+\alpha_0\lambda_0-\eta)}{\eta-\lambda_0-\delta_1}\frac{e^{(\lambda_1\overline{F}(w)+\delta_1-\eta)a}}{\lambda_1\overline{F}(w)+\delta_1-\eta}-\frac{c_4\eta}{\eta+(\alpha_0-1)\lambda_0}\frac{e^{(\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta)a}}{\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta}.
$$

Using $M_{m2}(w,0)=0$ to solve for C_2 in equation (37), and substituting the result into the same equation yields

$$
M_{m2}(w,a)
$$
$$
=\frac{\eta\alpha_0\lambda_0 F(w)c_3\delta_1}{\alpha_1\lambda_1\overline{F}(w)+\delta_1}\left[\frac{e^{-(\eta+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)+\delta_1-\eta}-\frac{e^{-(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{(1-\alpha_1)\lambda_1\overline{F}(w)-\eta}\right]
$$
$$
+\frac{\eta\alpha_0\lambda_0 F(w)c_4}{\alpha_1\lambda_1\overline{F}(w)-\alpha_0\lambda_0}\left[\frac{e^{-(\alpha_0\lambda_0+\eta+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta}-\frac{e^{-(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{(1-\alpha_1)\lambda_1\overline{F}(w)-\eta}\right]
$$
$$
+\lambda_0 F(w)c_1\delta_1\frac{e^{-\delta_2 a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)+\delta_1}+\lambda_0 F(w)c_2\frac{e^{-(\lambda_0+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)-\lambda_0}
$$
$$
+\lambda_0 F(w)c_3\frac{\delta_1(\delta_1+\alpha_0\lambda_0-\eta)}{\eta-\lambda_0-\delta_1}\frac{e^{-(\delta_2+\eta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)+\delta_1-\eta}
$$
$$
-\lambda_0 F(w)\frac{c_4\eta}{\eta+(\alpha_0-1)\lambda_0}\frac{e^{-(\alpha_0\lambda_0+\eta+\delta)a}-e^{-(\lambda_1\overline{F}(w)+\delta)a}}{\lambda_1\overline{F}(w)-\alpha_0\lambda_0-\eta}.
$$

The age-dependent earnings distribution of immigrants, given by $G_m(w,a)$, is

$$
G_m(w,a)=\frac{M_{m1}(w,a)+M_{m2}(w,a)}{E_{m1}(a)+E_{m2}(a)}. \tag{38}
$$

To show that $G_m(w,a)$ converges to the same distribution as $G_n(w,a)$, rewrite equa-

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tion (38) as

$$G_m(w, a) = \frac{e^{\delta_2 a}[M_{m1}(w, a) + M_{m2}(w, a)]}{e^{\delta_2 a}[E_{m1}(a) + E_{m2}(a)]} = \frac{e^{\delta_2 a}M_{m1}(w, a) + e^{\delta_2 a}M_{m2}(w, a)}{e^{\delta_2 a}E_{m1}(a) + e^{\delta_2 a}E_{m2}(a)}.$$

It is then straightforward to show the limits of the terms appearing in both the numerator and denominator.

$$\lim_{a \to \infty} e^{\delta_2 a}M_{m1}(w, a) = 0, \quad \lim_{a \to \infty} e^{\delta_2 a}M_{m2}(w, a) = \frac{\lambda_0 c_1 \delta_1 F(w)}{\lambda_1 \overline{F}(w) + \delta_1},$$

$$\lim_{a \to \infty} e^{\delta_2 a}E_{m1}(a) = 0, \quad \lim_{a \to \infty} e^{\delta_2 a}E_{m2}(a) = \lambda_0 c_1.$$

Therefore we obtain the desired result.

$$\lim_{a \to \infty} G_m(w, a) = \frac{\delta_1 F(w)}{\lambda_1 \overline{F}(w) + \delta_1}.$$

$\square$

Appendix B   Likelihood Contributions

For all individuals in the data set, the likelihood contributions account for their initially observed employment outcomes, the duration of the initial spell, and if applicable, the wages earned and transition made at the end of the spell. In addition to these pieces of information, the characteristics of the next spell also enter into the likelihood if the initial spell is an unemployment spell, or if it is a job spell that ends with a transition to an unemployment spell. More specifically, a list of variables used in the likelihood can be written as $x_i = (w_1, d_1, c_1, t_1, d_2, c_2)$ for those initially employed, where w_1 and d_1 represent the wage earned and duration of the initial job, c_1 takes on a value of 1 if the initial spell is censored and 0 otherwise, and t_1 takes on a value of 1 if the initial spell ends with a transition to a new job, and 0 if it ends with a transition to unemployment. If the initial spell ends with a transition to unemployment, d_2 represents the duration of the second spell, with c_2 being the indicator for censoring of the second spell. For those initially unemployed, x_i is given as $x_i = (d_1, c_1, w_2, d_2, c_2, t_2)$ with d_1 and c_1 representing the duration and censoring outcome of the unemployment spell, respectively, w_2, d_2 and c_2 representing the wage, duration and censoring outcome of the following job spell, respectively, and t_2

representing the type of transition made if the second spell is complete.

The likelihood contributions $L_n(\theta; x_i)$ and $L_{m2}(\theta; x_i)$ have the familiar structure in the job search literature because the search behaviours of the corresponding groups are standard. In contrast, derivation of $L_{m1}(\theta; x_i)$ involves accounting for possible changes in the search process among workers, and requires more careful presentation. We discuss derivations for these three in turn.

Derivation of $L_n(\theta; x_i)$ and $L_{m2}(\theta; x_i)$

In the steady state, a native worker is employed with probability $\lambda_0/(\lambda_0 + \delta)$, and the distribution of wages earned on that job is given by $G_n(w_1)$. Given the initial wage w, the residual duration of the first job spell follows the exponential distribution with parameter $(\lambda_1 \overline{F}(w) + \delta)$. At the end of a job spell, a native worker makes a job-to-job transition with probability $\lambda_1 \overline{F}(w)/(\lambda_1 \overline{F}(w) + \delta)$, or a job-to-unemployment transition with probability $\delta_1/(\lambda_1 \overline{F}(w) + \delta)$. The duration of a new unemployment spell follows the exponential distribution with parameter $(\lambda_0 + \delta_2)$ and ends with a transition to a new job with probability $\lambda_0/(\lambda_0 + \delta_2)$. Gathering all the components together, the likelihood contribution for native-born individuals initially employed is given by

$$\frac{\lambda_0}{\lambda_0 + \delta} g_n(w) e^{-(\lambda_1 \overline{F}(w) + \delta) d_1} \left[(\lambda_1 \overline{F}(w))^{t_1} (\delta_1 e^{-(\lambda_0 + \delta_2) d_2} \lambda_0^{1-c_2})^{1-t_1} \right]^{1-c_1}$$

where $g_n(w)$ denotes the density of $G_n(w)$.

The probability that a native individual is unemployed in the steady-state is $\delta/(\lambda_0 + \delta)$. The residual unemployment duration follows the exponential distribution with parameter $(\lambda_0 + \delta_2)$, and the probability that an unemployment spell ends with a transition to a new job as opposed to a permanent exit from the labour market is given by $\lambda_0/(\lambda_0 + \delta_2)$. The distribution of wages on new jobs is given by $F(w)$. The duration of a new job follows the exponential distribution with parameter $(\lambda_1 \overline{F}(w) + \delta)$, and ends with a transition to a job spell with probability $\lambda_1 \overline{F}(w)/(\lambda_1 \overline{F}(w) + \delta)$ or with a job-to-unemployment transition with probability $\delta_1/(\lambda_1 \overline{F}(w) + \delta)$. Therefore, the likelihood contribution for native workers initially unemployed takes the form

$$\frac{\delta}{\lambda_0 + \delta} e^{-(\lambda_0 + \delta_2) d_1} \left[\lambda_0 f(w) e^{-(\lambda_1 \overline{F}(w) + \delta) d_2} \left(\delta_1^{1-t_2} (\lambda_1 \overline{F}(w))^{t_2} \right)^{1-c_2} \right]^{1-c_1}.$$

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The likelihood contribution for type 2 immigrants is similar to the natives' since they share the same search process. $L_n(\theta, x_i)$ and $L_{m2}(\theta_i, x_i)$ differ due to differences in the probabilities of the initial employment status and earned wage. The probability that a type 2 immigrant worker is employed at any instance is given by

$$\frac{\lambda_0(\delta + \eta + \alpha_0\lambda_0 + \alpha_0\delta_2)}{(\lambda_0 + \delta)(\delta + \eta + \alpha_0\lambda_0)},$$

and the distribution of the wage earned is given by $G_{m2}(w)$ with its density denoted by $g_{m2}(w)$. The steady-state probability that a type 2 immigrant worker is unemployed is given by

$$\frac{\delta((\delta + \eta) + \delta_1\alpha_0\lambda_0)}{(\lambda_0 + \delta)(\delta + \eta + \alpha_0\lambda_0)}.$$

Thus, $L_{m2}(\theta, x_i)$ takes the form

$$\frac{\lambda_0(\delta + \eta + \alpha_0\lambda_0 + \alpha_0\delta_2)}{(\lambda_0 + \delta)(\delta + \eta + \alpha_0\lambda_0)} g_{m2}(w) e^{-(\lambda_1\overline{F}(w)+\delta)d_1} \left[(\lambda_1\overline{F}(w))^{t_1} (\delta_1 e^{-(\lambda_0+\delta_2)d_2} \lambda_0^{1-c_2})^{1-t_1} \right]^{1-c_1}$$

for those initially employed, or

$$\frac{\delta((\delta + \eta) + \delta_1\alpha_0\lambda_0)}{(\lambda_0 + \delta)(\delta + \eta + \alpha_0\lambda_0)} e^{-(\lambda_0+\delta_2)d_1} \left[\lambda_0 f(w) e^{-(\lambda_1\overline{F}(w)+\delta)d_2} \left(\delta_1^{1-t_2} (\lambda_1\overline{F}(w))^{t_2} \right)^{1-c_2} \right]^{1-c_1}$$

for those initially unemployed.

Derivation of $L_{m1}(\theta; x_i)$

Derivation of $L_{m1}(\theta; x_i)$ is more involved because of the possibility that type 1 immigrants experience changes in search parameters. It is therefore helpful to introduce variables reflecting immigrant types upon transitions between spells. The variables, denoted y_1 and y_2, are used to first form the joint probabilities with the observed outcomes, and then integrated out to yield the expression for $L_{m1}(\theta; x_i)$. This process results in the following expression of the likelihood contribution of type 1 immigrants who are initially unemployed:

$$P_U \sum_{y_1=1}^{2} \left[P_{u1}(d_1, y_1, c_1) \left[f(w) \sum_{y_2=y_1}^{2} P_{j2}(d_2, y_2, c_2|w, y_1) P_{tr}(t_2|w, y_2)^{1-c_2} \right]^{1-c_1} \right]$$

where P_U represents the probability that a type 1 immigrant is unemployed at any instant in the steady state, i.e., $P_U = (\delta + \eta)/(\delta + \eta + \alpha_0\lambda_0)$. Component probability $P_{u1}(d_1, y_1, c_1)$ is the joint probability of the residual unemployment duration, censoring indicator and the ending immigrant type of the first spell. $f(w)$ is the distribution of accepted wage offers. $P_{j2}(d_2, y_2, c_2|w, y_1)$ is the joint probability of the duration, censoring outcome and ending immigrant type of the following job spell conditional on the accepted wage and the starting immigrant type on the job. The last factor, $P_{tr}(t_2|y_2, w)$, accounts for the type of transition made at the end of the second spell.

Similarly, for type 1 immigrants seen initially employed, the likelihood contribution takes the form

$$
P_E g_{m1}(w) \sum_{y_1=1}^{2} \left[P_{j1}(d_1, y_1, c_1|w) \left[P_{tr}(t_1|w, y_1) \left(\sum_{y_2=y_1}^{2} P_{u2}(d_2, y_2, c_2|y_1) \right)^{1-t_1} \right]^{1-c_1} \right]
$$

where P_E denotes the probability that a type 1 immigrant is employed at any instant in the steady state, i.e., $P_E = \alpha_0\lambda_0/(\delta + \eta + \alpha_0\lambda_0)$, and $g_{m1}(w)$ is the density of the steady state earned wage distribution for type 1 immigrants. Component probability $P_{j1}(d_1, y_1, c_1|w)$ is the joint probability of the residual duration, censoring outcome and the ending immigrant type of the first job spell, and $P_{tr}(t_1|w, y_1)$ is the probability of the observed transition from the job spell. For those who transition to unemployment, $P_{u2}(d_2, y_2, c_2|y_2)$ accounts for the joint probability of the duration, ending immigrant type and censoring indicator of the following unemployment spell .

Having presented the overall structure of the likelihood contribution, we now provide the expressions for its components. If an immigrant remains as type 1 during his first observed spell, the residual duration of the spell follows the exponential distribution with parameter $(\alpha_0\lambda_0 + \delta_2)$ if it is an unemployment spell, or with parameter $(\alpha_1\lambda_1\overline{F}(w) + \delta)$ if it is a job spell. Therefore for $y_1 = 1$, $P_{u1}(d_1, c_1, y_1)$ and $P_{j1}(d_1, c_1, y_1|w)$ are given by, respectively,

$$
P_{u1}(d_1, c_1, 1) = (\alpha_0\lambda_0 + \delta_2)^{1-c_1} e^{-(\alpha_0\lambda_0 + \delta_2 + \eta)d_1} \tag{39}
$$

and

$$
P_{j1}(d_1, c_1, 1|w) = (\alpha_1\lambda_1\overline{F}(w) + \delta)^{1-c_1} e^{-(\alpha_1\lambda_1\overline{F}(w) + \delta + \eta)d_1}. \tag{40}
$$

If immigrants change types during the first spell, i.e., $y_1 = 2$, the duration of the

spell can be given as the sum of two independent exponential random variables. If the spell is an unemployment spell, the relevant two variables are exponential with parameters $(\alpha_0\lambda_0+\eta+\delta_2)$ and $(\lambda_0+\delta_2)$. Letting s and $(d-s)$ denote the realizations of these two variables, the distribution of their summed value, d, is given by

$$\int_0^d \left(e^{-(\alpha_0\lambda_0+\eta+\delta_2)s}\eta\right)\left(e^{-(\lambda_0+\delta_2)(d-s)}(\lambda_0+\delta_2)\right)ds$$
$$= \frac{\eta(\lambda_0+\delta_2)}{(\alpha_0-1)\lambda_0+\eta}\left(e^{-(\lambda_0+\delta_2)d}-e^{-(\alpha_0\lambda_0+\eta+\delta_2)d}\right).$$

The probability that a completed unemployment spell ends with a transition to a job is $\lambda_0/(\lambda_0+\delta_2)$, therefore for $y_1=2$ and $c_1=0$, $P_{u1}(d_1,y_1,c_1)$, is given by

$$P_{u1}(d_1,2,0) = \frac{\eta\lambda_0}{(\alpha_0-1)\lambda_0+\eta}\left(e^{-(\lambda_0+\delta_2)d_1}-e^{-(\alpha_0\lambda_0+\eta+\delta_2)d_1}\right). \tag{41}$$

If the spell is censored, i.e., $c_1=1$, the relevant expression for $P_{u1}(d_1,y_1,c_1)$ is given by

$$\begin{aligned}
P_{u1}(d_1,2,1) &= \int_{d_1}^\infty \frac{\eta(\lambda_0+\delta_2)}{(\alpha_0-1)\lambda_0+\eta}\left(e^{-(\lambda_0+\delta_2)\tau}-e^{-(\alpha_0\lambda_0+\eta+\delta_2)\tau}\right)d\tau \\
&= \frac{\eta(\lambda_0+\delta_2)}{(\alpha_0-1)\lambda_0+\eta}\left[\frac{e^{-(\lambda_0+\delta_2)d_1}}{\lambda_0+\delta_2}-\frac{e^{-(\alpha_0\lambda_0+\eta+\delta_2)d_1}}{\alpha_0\lambda_0+\eta+\delta_2}\right]. \tag{42}
\end{aligned}$$

Analogously, if a type 1 immigrant become a type 2 immigrant during a job spell, the spell duration is the sum of two independent exponential random variables with parameters, respectively, $(\alpha_1\lambda_1\overline{F}(w)+\eta+\delta)$ and $(\lambda_1\overline{F}(w)+\delta)$. If it is a completed spell, i.e., $c_1=0$, the expression for $P_{j1}(d_1,y_1,c_1|w)$ is given by

$$\begin{aligned}
P_{j1}(d_1,2,0|w) &= \int_0^{d_1} e^{-(\alpha_1\lambda_1\overline{F}(w)+\delta+\eta)s}\eta e^{-(\lambda_1\overline{F}(w)+\delta)(d_1-s)}(\lambda_1\overline{F}(w)+\delta)ds \\
&= \frac{\eta(\lambda_1\overline{F}(w)+\delta)}{(\alpha_1-1)\lambda_1\overline{F}(w)+\eta}\left(e^{-(\lambda_1\overline{F}(w)+\delta)d_1}-e^{-(\alpha_1\lambda_1\overline{F}(w)+\delta+\eta)d_1}\right). \tag{43}
\end{aligned}$$

If it is censored, it is given by

$$P_{j1}(d_1, 2, 1|w) = \int_{d_1}^{\infty} P_{j1}(\tau, 2, 0|w)d\tau$$

$$= \frac{\eta(\lambda_1 \overline{F}(w) + \delta)}{(\alpha_1 - 1)\lambda_1 \overline{F}(w) + \eta} \left[\frac{e^{-(\lambda_1 \overline{F}(w) + \delta)d_1}}{\lambda_1 \overline{F}(w) + \delta} - \frac{e^{-(\alpha_1 \lambda_1 \overline{F}(w) + \delta + \eta)d_1}}{\alpha_1 \lambda_1 \overline{F}(w) + \delta + \eta} \right]. (44)$$

If an immigrant starts the second spell as a type 1 immigrant, i.e., $y_1 = 1$, the component probabilities given in equations (39) – (44) apply, so that $P_{u2}(d_2, c_2, y_2|y_1 = 1) = P_{u1}(d_2, c_2, y_2)$ and $P_{j2}(d_2, c_2, y_2|w, y_1 = 1) = P_{j1}(d_2, c_2, y_2|w)$. If an immigrant is of type 2 at the start of a spell, the duration of the spell follows the exponential distribution with parameter $(\lambda_0 + \delta_2)$ if it is an unemployment spell or with parameter $(\lambda_1 \overline{F}(w) + \delta)$ if it is a job spell. Therefore for $y_1 = y_2 = 2$, $P_{u2}(d_2, y_2, c_2|y_1)$ and $P_{j2}(d_2, y_2, c_2|y_1)$ are, respectively,

$$P_{u2}(d_2, 2, c_2|2) = (\lambda_0 + \delta_2)^{1-c_2} e^{-(\lambda_0 + \delta_2)d_2},$$

and

$$P_{j2}(d_2, 2, c_2|w, 2) = (\lambda_1 \overline{F}(w) + \delta)^{1-c_2} e^{-(\lambda_1 \overline{F}(w) + \delta)d_2}.$$

For $j \in \{1, 2\}$, $\mathrm{P}_{tr}(t_j|w, y_j)$ is the component probability of the transition outcome from a job spell. Depending on the ending immigrant type, it is given by

$$\mathrm{P}_{tr}(t_j|w, y_j = 1) = \frac{(\alpha_1 \lambda_1 \overline{F}(w))^{t_j} \delta_1^{1-t_j}}{\alpha_1 \lambda_1 \overline{F}(w) + \delta},$$

or

$$\mathrm{P}_{tr}(t_j|w, y_j = 2) = \frac{(\lambda_1 \overline{F}(w))^{t_j} \delta_1^{1-t_j}}{\lambda_1 \overline{F}(w) + \delta}.$$

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