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IZA DP No. 11801

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ABSTRACT

Basic Information and Communication Technology Skills among Canadian Immigrants and Non-Immigrants*

Male immigrants are observed to be disproportionately employed in ICT information and communication technology (ICT) industries and occupations. A measure of basic ICT skills is employed to document differences in skill levels and labour market earnings across immigration classes and categories of Canadians at birth. Adult immigrants, including those assessed by the points system, are found to have lower average ICT scores than Canadians at birth, although the rate of return to ICT skills is not statistically different between them. Immigrants who arrive as children, and the Canadian-born children of immigrants, have similar outcomes to the Canadian-born children of Canadian-born parents.

JEL Classification: J24, J31

Keywords: information and communication technologies (ICT), skills, immigration, PIAAC, problem-solving in technology-rich environments (PSTRE), digital literacy, problem-solving; skill shortage

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* This project was undertaken in the Research Data Center at McMaster University, which is a part of Statistics Canada's Research Data Center Network. We would like to thank the RDC analysts for their help regarding the data. We also thank participants at the 51st Annual Conference of the Canadian Economics Association. The views expressed in this paper are our own and do not necessarily repre-sent the views of Statistics Canada. Any errors remain ours. An Online Appendix for this paper with sensitivity tests and the like can be found on the EPRI website: http://www.epri.ca/. Sweetman holds the Ontario Research Chair in Health Human Resources, which is endowed by Ontario's Ministry of Health and Long-Term Care; all views expressed are his own and not necessarily those of the Province of Ontario.

1. Introduction

Information and communication technologies (ICTs) affect many aspects of our daily lives and workplaces. In 2016, 76 percent of Canadians owned a smartphone, and approximately 71 percent possessed a laptop or netbook computer (Statistics Canada 2017). Digital technologies have also changed the practices and operations of businesses and governments (OECD 2017), and having ICT-related skills is essential for workers to participate in the digital economy (ICTC 2016a; Cameron and Faisal 2016). ICT skills are sometimes categorized into three: specialist or advanced, generic, and complementary (OECD 2017; Spiezia et al. 2016). Specialist skills are required to produce ICT products and service those products. Generic ICT skills facilitate the use of ICT products/technologies to carry out tasks at home and work. Skills that complement ICT technologies permit individuals to efficiently execute a wide variety of tasks – ones that are not always directly categorized as ICT tasks – in technology-rich environments.

This paper focuses on the intersection of immigration and the labour market demand for ICT skills. As a major immigrant-receiving country, Canada is, in broad terms, interested in understanding immigrants' integration into the digital economy since the demand for general-purpose technology skills (i.e., generic and complementary ICT skills) is increasing (OECD 2017). Immigration is also sometimes posited as one avenue to address specialist/advanced ICT-related labour and/or skill shortages in the Canadian economy. For example, the Information and Communications Technology Council (ICTC 2016b) reports that 877,470 ICT professionals were employed throughout the economy as of December 2015, and proposes that 182,000 additional hires will be needed by 2019. (See also OECD 2017; ICTC 2011; Nordicity 2012;

ICTC 2016b).[1] Given the data employed in this analysis, there are limits to what can be said regarding the recruitment of ICT specialists – although some useful information will be presented. In contrast, the data are well suited to the first, more broad-based, goal of looking across immigration-related population subgroups in order to document levels of basic ICT skills and estimate the deployment and economic rates of return to such skills in the labour market.

Alongside projections of ICT labour and skill shortages, technology advances are simultaneously associated with decreasing future labour demand in general. Johal and Thirgood (2016) argue that approximately one million workers may lose their jobs in the next few decades, and part-time/temporary jobs may replace many Canadians' full-time/permanent positions, due to the rise of automation. Related to this, Acemoglu and Restrepo (2017) find that robots or computer-assisted technologies have a negative influence on employment and wages. They estimate that one extra robot per thousand workers reduces wages by 0.25 to 0.50 percentage points and employment by 0.18 to 0.34 percentage points. However, Autor (2015) argues that automation can be both a substitute and complement to labour. Coupled with the evidence above, OECD (2017) suggests that the skills embodied in the workforce are a key concern for economic growth and emphasizes the importance of ICT-related skills (re-)training to facilitate the effective use of these technologies.

The intersection of the labour market integration of immigrants and the increasing demand for ICT skills, both advanced and generic, is much discussed but not well understood. Further, in Canada foreign-trained workers, including those in the ICT sector, face skill mismatches including those resulting from differences in education systems, language barriers

[1] Despite the shortage discourse, there is no consensus on how to measure either labour or skills shortages, and the historical track record of projecting shortages does not instill confidence among many labour market analysts (e.g., Freeman 2006; Barnow et al. 2013).

and ethnic discrimination (ICTC 2016a; Warman et al. 2015; Clarke and Skuterud 2016; Picot and Sweetman 2012).

We document the distribution of immigrants and the Canadian-born across ICT industries and occupations, as well as the self-reported use of various technologies in the workplace, including complex ICT skills and programming. Further, we employ a direct measure of basic skills related to problem-solving in technology-rich environments from Statistics Canada's 2012 Survey of Adult Skills, which is a part of the Organization for Economic Cooperation and Development's (OECD's) Programme for the International Assessment of Adult Competencies (PIAAC) (OECD 2012). It measures a combination of generic ICT skills and skills that are complementary to ICT. This direct measure is not intended to quantify specialist skills, though some observers might expect highly skilled ICT specialists to also have high levels of basic ICT skills. Indeed, if they do not, then such specialist workers' capacity to recover in the face of negative economic shocks may be limited, a phenomenon observed in the so-called ICT bust documented by Picot and Hou (2009). In the rapidly evolving ICT sector, career advancement and employment transitions may also be affected if workers' skill sets, though advanced, are extremely narrow.

Of course, there is a high correlation between the ICT scores employed, and numeracy and English/French literacy. Moreover, the basic ICT test is written in English or French. Thus the measured ICT scores likely also reflect other skills, especially English/French proficiency. As posited by Warman et al. (2015), it seems reasonable to assume that workplace language/communication skills mediate the use of other skills. Overall, these scores reflect the ability to undertake a range of basic ICT-related tasks in an English/French work (or home) environment, not the skills required for advanced ICT tasks.

We also extend the broad literature on immigrants' labour market integration. On this dimension, we distinguish between adult immigrants (i.e., the first generation) and child immigrants (termed the 1.5 generation). We also differentiate between Canadians at birth born outside of Canada with at least one parent a Canadian citizen and, for those born in Canada, we distinguish between the children of at least one immigrant parent (i.e., second-generation immigrants) and the Canadian-born children of two Canadian-born parents (i.e., third-generation immigrants, or perhaps more accurately the third-plus-generation). We also align our analysis with immigration policy by contrasting across immigration classes. Previous analyses by immigration class (Aydemir 2013; Sweetman and Warman 2010, 2013) and immigrant generations (Sweetman and Van Ours 2014) relative to domestic citizens at birth are relevant background. Finally, we also separately identify temporary residents (comprising temporary workers, foreign students and others) given the increasing interest in this group (e.g., Sweetman and Warman 2014; El-Assal and Sweetman 2016).

Although we focus on basic ICT skills, research involving literacy and numeracy skills in the labour market, especially for immigrants, is relevant to this study. Green and Riddell (2003), using the Canadian portion of the 1994 International Adult Literacy Survey (IALS), find controlling for literacy skills in earnings regressions reduces the coefficient on years of schooling. In their international comparison of the returns to numeracy skills, Hanushek et al. (2015) estimate that a one-percent increase in numeracy is associated with an 18 percent increase in earnings. At the intersection of these measured skills and immigration, Ferrer, Green, and Riddell (2006) observe that differences in literacy skills explain about two-thirds of the earnings gap between university-educated native-born and immigrants, and eliminate differences in the rate of return to education. At a more aggregate level, Li and Sweetman (2014) observe that for adult immigrants higher average test scores for source country education systems are associated with higher rates of return to education in the Canadian labour market. Overall, this literature points to the high value placed on literacy and numeracy skills in the labour market and their correlation with rates of return to education.

Even though male immigrants who entered under the points system are more likely to have jobs involving complex ICT skills and computer programming, we observe that these individuals, together with other foreign-educated individuals, are on average less proficient according to our basic ICT measure compared to third generation Canadians. This deficit is in general made stronger by controlling for characteristics including the highest level of education attained. This may be consistent with the labour market fragility of immigrants in adjustments subsequent to a negative economic shock in the ICT sector, such as that documented by Picot and Hou (2009). In contrast, young immigrants, those who arrive in Canada at age 12 or younger, have basic ICT proficiency comparable to the third-generation; and second-generation Canadians on average have better problem-solving skills using digital tools than the third-generation. However, this advantage is entirely accounted for by different levels of education, consistent with Aydemir and Sweetman (2008). Overall, the results suggest that while adult immigrants disproportionately fill ICT-related positions, they are on average not as proficient in basic ICT skills as Canadians-by-birth and young immigrants.

Importantly, we observe an appreciable economic return in the labour market to having modest levels of even the basic ICT skills (as opposed to no ICT skills whatsoever or very minimal skills), and this return exists even after taking literacy and numeracy into account. That is, even though our measure of ICT skills encompasses only very basic tasks, our evidence suggests that there is a very substantial earnings premium at the very low end of the scale. This return exists even controlling for literacy and numeracy. Although our observations are non-causal, they point out the substantial potential economic value of ICT skills beyond the most basic levels for immigrants and non-immigrants alike. If the results reflect, even in part, a causal impact of these skills, then programs to provide very basic ICT skills would have a substantial rate of return. These skills could potentially be incorporated into the curriculum of English/French language training programs already offered to new immigrants at low (or zero) cost. Such basic skills seem to be associated with workers who are far from specialists, but who engage in the digital economy in a manner that is rewarded in the labour market. Further, the introduction of these extremely basic skills could be incorporated into many skills training programs provided by, for example, the Employment Insurance Part II for the general population. This needs not be an expensive undertaking; it could be accomplished by adjusting the curriculum of existing programs.

Our analysis suggests that a one standard deviation increase in the basic ICT score, on average, translates into seven percent higher earnings for both males and females. We also find that the labour market does seem to reward foundational ICT skills proficiency at an equal rate between immigrant and Canadian groups within gender. The earnings gaps between each immigrant category relative to third-generation Canadians are rendered statistically insignificant when controlling for ICT, literacy and numeracy test scores. Both young immigrants who undertake a substantial portion of their education in Canada and second-generation Canadians have similar problem-solving abilities in technology-rich environments as their third-generation counterparts and make a marked contribution to the ICT workforce.

The remainder of this paper is organized as follows. Section 2 describes the data used in the analysis. Section 3 discusses the analytical framework. Section 4 discusses the results and section 5 concludes.

2. Data and descriptive statistics

We employ Statistics Canada's 2012 Survey of Adult Skills, which is a product of the OECD's PIAAC (OECD 2012, 2013a, 2013b). It collects information on labour supply, wages, education, and a range of demographic characteristics. Crucially, it assesses three "key information-processing competencies" of individuals by evaluating their proficiency in literacy, numeracy, and problem-solving in technology-rich environments (i.e., basic ICT skills). We focus on the last which assesses how effectively individuals use ICT tools to solve simple tasks, rather than measuring advanced ICT skills (Rouet et al. 2009). The measurement scale ranges from zero to 500. It uses classical item response theory and a multiple imputation method to derive ten plausible values for each test score. Also, a survey weight is provided for each respondent. See the appendix for a discussion of how estimation is undertaken in the presence of these survey design issues.

Online Appendix Table 1 examines the correlation between the three tests for various subsamples of the data. The results are similar across subsamples. For the entire sample literacy and numeracy are the most highly correlated at 0.87, while numeracy and the basic ICT score are the least correlated at 0.75. It is unclear to what extent the tests are measuring the same underlying skills, versus the degree to which distinct underlying skills are positively correlated across individuals.

Our sample for analysis includes 16,379 individuals aged 22 to 59 who have valid information on all relevant variables other than the ICT score. Among these, 13,547 have valid

ICT scores.[2] For some of the analysis, we also categorize workers into ICT, and non-ICT, occupations and industries as defined in Appendix Table A1. However, the sample size is too small to permit us to look at ICT occupations within ICT industries. Because of a concern that high earning outliers may be driving some of the results, the body of the paper employs data with the top half of one percent of earnings Winsorized. That is, all earnings in the top 0.5 percent are capped at the 99.5 percentile of earnings. The online appendix presents a number of tables not employing this restriction and the results are, despite this concern, essentially unchanged.

By immigration status and sex, Table 1 displays mean test scores and employment distributions for ICT/non-ICT occupations and industries. Focusing first on the employment distribution across occupations for male immigrants, it can be seen in Table 1 that about 11 percent of immigrant men work in ICT occupations, compared to only about 5.2 percent of Canadian-born men. Clearly, immigrant males are disproportionately employed in ICT occupations. When the sample is restricted to those with an ICT score, the percentage of immigrant men in the ICT industry increases to 13.7 percent whereas the Canadian born share increases only slightly to 5.8 percent. That the share of workers in ICT occupations increases, and increases more considerably for immigrants, reflects the dissimilar probabilities of respondents having insufficient skills to do the ICT test. These issues are pursued in Tables 2 and 7.

In contrast to males, immigrant and Canadian-born females are approximately equally likely to work in ICT occupations, but for both the probabilities are only about two percent. Looking at the test scores, workers in ICT occupations have higher ICT, literacy and numeracy

[2] Only those who completed the computer-based core assessments are assessed for ICT skills since test-takers need to at least be familiar with graphical interfaces. However, literacy and numeracy scores are available for a wider group since non-ICT respondents write paper-based literacy and numeracy assessments. A small number of people refuse to attempt the computer-based assessment.

scores compared to those not in ICT occupations. Also, within the ICT industry, the Canadian born have higher average scores in all three categories than do immigrants.

Turning to industries in the lower half of the table, immigrant males are again more likely to work in ICT than the Canadian-born, although the reverse is true for females. Note that each industry includes a wide variety of occupations (e.g., an accountant or janitor might work for a firm in an ICT industry). The patterns of test scores are broadly similar for males by industry as occupation, but the pattern is less clear-cut for females.

In terms of immigration status, as depicted in the columns of Table 2, we classify the population into the nine exhaustive and mutually exclusive categories refugee, points-based immigrants, family-reunification, and other immigrants (including, e.g., the live-in-caregiver stream and unknown/refused); temporary residents; young immigrants (arrived at age 12 or younger regardless of their parents' immigration class); and Canadians by birth who are born abroad or are in the second- or third-generation. Separately, those who do not have basic ICT scores are grouped into four categories: no prior computer experience, failed ICT core tests, refused to attempt computer-based assessment, and "others" with no ICT score. As this last (very small) group is not clearly defined by Statistics Canada, we exclude these individuals from our sample.

The percentage of each sub-group not taking the computer-based assessment, the distribution of scores for those taking it, and the population share of each sub-group are presented in Table 2. Approximately 38 percent of both refugee and family reunification categories did not take the ICT test (a rate dramatically higher than that for young immigrants or the second-generation). Large differences in the distribution of levels of basic ICT skills can also be seen across these groups for those able and willing to take the test. Roughly 48–55 percent of young immigrants, the second generation, and Canadians by birth born outside of Canada are likely to score in the highest third of test takers, whereas only seven percent of refugees and 15 percent of family reunification immigrants are likely to do so respectively. Surprisingly, only 29 percent of points-based immigrants who wrote the test scored in the top third. Overall, there are dramatic differences in ICT usage and basic skills across these population categories. While we can only speculate about the relationship between specialist ICT skills and these basic skills, some concern may be warranted regarding ICT specialists, many of whom, as will be seen, are in the points-based immigrant stream, who are unable to score in the “high” category on this relatively simple test.

Table 3 shows average characteristics by population sub-category. The uppermost part of the table shows average literacy, numeracy and basic ICT scores. Apart from those who arrived young, immigrants (even points-based immigrants) have, on average, lower scores than the Canadian categories for all three tests. Looking at the demographic characteristics, the average age at immigration for young immigrants is around six years old, so most received the bulk of their formative education in Canada. As has been observed previously (e.g., Sweetman and Van Ours 2014), the Canadian education system appears quite effective in integrating young immigrants. For Canadians born overseas, age at immigration should be interpreted as the average age at which they permanently moved to Canada. Also notable is that temporary residents are, on average, five to 11 years younger than individuals in other categories. We see also that immigrants in the refugee, family reunification, and other immigration categories as well as temporary residents have noticeably lower average wages than all the others. Finally, foreign-born individuals are also much more likely to reside in large urban population centres;

compared to the third-generation, these groups on average operate in relatively different labour markets and face different competition in the labour market.

Turning to education, in the bottom panel of Table 3, approximately 65 percent of points-based immigrants hold a Bachelor's degree or higher, which is by far the highest proportion across categories and contrasts with their test scores further up the column. On the other hand, the educational distribution of the third generation and refugees is quite surprisingly similar with only about 24 to 25 percent having at least a Bachelor's degree. Among those with a postsecondary degree, the proportion whose field is in science, technology, engineering or mathematics (STEM) is markedly higher among the points-based category than any other, with temporary residents having the second-highest share. Refugees with a college/trade diploma have a higher percentage with STEM than do either the second- or third-generation Canadians with diplomas. Most immigrants, except for young immigrants, complete their highest level of education outside of Canada. The vast majority of young immigrants and the second and third generation attain their highest level of education in Canada, with Canadians born overseas having an intermediate percentage.

The PIAAC includes a variety of useful questions regarding computer use at work that are analyzed in Table 4 for those employed at the time of the survey.[3] Each question is, or is converted into, a simple yes (dependent variable equals 1) or no (equals zero), and the models are estimated using a linear probability model.[4] Coefficients from a set of age-adjusted regressions exploring differences across the population groupings are presented (with two sets of population sub-groups, as seen in the table) with the female variable interacted with each of the

[3] Online Appendix Table 2 has a similar table for the larger set of those employed at any time during the 12 months before the survey. The results are similar.

[4] Nonlinear models, such as *probit*, are not employed given the plausible values aspect of the data and because heteroscedasticity of unknown form is a potential problem.

population subgroup variables. The age variable is adjusted by subtracting 40 from each respondent's age so that the constant reflects the probability of a positive response for an average person in the omitted/comparison group: a 40-year-old male third-generation Canadian. All other population subgroup coefficients represent average age-adjusted differences relative to that category.

As seen in Table 4, among males, points-based and young immigrants, and the second-generation are statistically more likely than the Canadian-born third-generation to use a computer at work, whereas refugees/family class immigrants are less likely to do so (with some groups collapsed for sample size considerations). With exceptions, this basic pattern continues for males across the next three columns looking at the use of email, spreadsheets, and word processors. Subsequent columns address highly skilled ICT tasks: whether the respondent undertakes computer programming at work, or whether their job requires complex ICT skills. In these cases, point-based immigrants have a uniquely high probability of working in jobs requiring these more technical ICT skills – for the point-based, there is a nontrivial difference illustrating immigrants' connection to the ICT sector (IRCC 2017). However, the differences across the other population sub-groups are much smaller and statistically insignificant. Though they are more likely to use a computer at work, young immigrants and second-generation Canadians have equal probabilities of working at jobs that require complex ICT skills compared to the third generation. Paradoxically, but perhaps consistent with the results seen in the previous tables, points-based male immigrants are more likely to report lacking the requisite ICT skills for getting a new job or a promotion although they report a similar (marginally higher) probability of having sufficient ICT skills for their current positions compared to the third-generation.

Turning to females, the third-generation is more likely to use a computer, and to do word processing, at work than their male counterparts, but less likely to program computers or to have a job requiring complex ICT skills. Perhaps surprisingly, points-based female immigrants are not more likely to use computers at work than third-generation females, and they are less likely to be employed in jobs requiring complex ICT skills. Indeed, all the female groups are less likely to have jobs requiring computer programming or complex ICT skills than third-generation males.[5]

For both sexes combined (because of the limited sample size), Figures 1 and 2 present nonparametric kernel density plots of the distribution of ICT scores for each of the immigrant groups compared, in each case, to the third-generation, which serves as a benchmark. Figure 1 looks at the subpopulation with a high school diploma or less, and Figure 2 focuses on those with a bachelor's degree or higher. It is evident from these graphs that analyses of the means of the distributions mask substantial heterogeneity. Nevertheless, for some of these groups, the distributions have quite different shapes, with the differences being almost everywhere more substantial among those with higher levels of education (except for the young immigrants and the second-generation, which have virtually identical distributions to the third-generation in both education categories). Universally, the Canadian born third-generation with at least a university degree has a distribution of ICT skills, as measured by this OECD metric, that is equivalent to or to the right/higher than (stochastically dominates) those of the other groups. Interestingly, the distribution of ICT skills for the points-based immigrants looks somewhat similar for those with high school and university education. Indeed, the distribution for both looks very similar to that

[5] Online Appendix Tables 3 and 4 examine the probability of working in an ICT industry or occupation in a framework similar to that in Table 4. For males, points-based immigrants and "other" immigrants are more likely to work in an ICT industry, and points-based immigrants and young immigrants are more likely to work in an ICT occupation.

for the third-generation with high school but recall that the samples are restricted to those with sufficient skills to write the test.

3. Empirical Framework

Our analysis begins by examining the correlates of the basic ICT (i.e., problem-solving in technology-rich environments, or PSTRE, skills) scores by population sub-category. Subsequently, we look at earnings gaps across the categories, in turn looking at the sub-sample of those with basic ICT scores and then the entire population, documenting how the gaps alter when ICT skills are considered. In all cases, variables are entered cumulatively from left to right, so the leftmost model is the "base" case and each subsequent model has the same regressors of that to its left plus additional ones. Interactions of various regressors are also undertaken in some specifications. The analysis is conducted separately for males and females. Multivariate ordinary least squares (OLS) models are employed with methodological details in the appendix. For these regressions, respondents' test scores have been standardized to mean zero and variance one. In the first stage of the analysis, therefore, the units of the coefficients are standard deviations of test scores.

First, for each self-reported sex we estimate:

$$BasicICT_i = \beta_0 + \mathbf{PopGroup_i}\boldsymbol{\beta_1} + X_i\beta_2 + \epsilon_i. \qquad (1)$$

by ordinary least squares (OLS) where $BasicICT_i$ are individual PSTRE scores. Importantly for interpretation, whereas in the descriptive statistics to this point we have presented simple test scores, in the regressions we standardize all three test score variables to mean zero and standard deviation 1.[6] Where relevant, therefore, the units of measure of the coefficients involve standard deviations of test scores. The nine population sub-groups are represented by, $\mathbf{PopGroup}$, a

[6] We standardize the basic ICT test score using relevant statistics for individuals who have valid test scores.

vector of indicators with the third generation omitted, and X is a vector of control variables which change across specifications. Covariates include age and age^2, education (below high school, high school diploma, post-secondary education (PSE) below Bachelor's (college/trade), and PSE with Bachelor's and above), and geography (11 provincial indicators and four urban/rural ones). We control for whether individuals obtained education in a foreign country, and if an individual graduated with a STEM degree. The foreign education indicator is individuals' self-reported highest level of qualification attained outside of Canada. As indicated in Table 3, a large proportion of immigrants and a quarter of Canadian-born overseas obtained their highest level of education outside of Canada. There is a small percentage of second and third generation Canadians who attained their education in a foreign country. By design, we do not account for years since migration, since we are interested in differences holding age constant. We address age-at-immigration (which is jointly collinear with years since migration and age) by separating our sample into adult and child immigrants. In some specifications, we include interactions between foreign education and the highest education attainment. The β's are coefficients to be estimated and ε is a possibly heteroskedastic error term. The vector of coefficient β_1 shows the average standard deviation PSTRE scores of each immigration category. As PIAAC 2012 requires individuals to have computer skills and language ability to identify and solve problems given to them in PSTRE and that all test scores are highly correlated, β_1 picks up differences in both basic computer skills and language ability among immigrants and Canadian categories.[7] Due to cross-section nature of our data, we are unable to clearly distinguish aging and cohort effects of the coefficient on age.

[7] The mean standard deviation differences between immigration categories, β_1, can be biased due to measurement errors and omitted values. Measurement errors arise because of the imputation method of plausible values. Furthermore, omitted-variable bias may affect the results because of unobservable characteristics, such as

In the second part of the analysis, we estimate the following individual-level wage regression, by sex:

$$\ln(HourlyWage_i) = \gamma_0 + \mathbf{BasicICT_i}\boldsymbol{\gamma_1} + \boldsymbol{PopGroup}_i\,\boldsymbol{\gamma_2} + X_i\gamma_3 + \mu_i. \qquad (2)$$

where $\ln(HourlyWage_i)$ is the natural logarithm of gross hourly wages earned by individuals i, the γ's are coefficients to be estimated and μ is a potentially heteroskedastic error term. Hourly wages at the top 0.5 percent are recoded to CAD 112.98.[8] In subsequent specifications, the **BasicICT** and selected X variables are added to observe how the ***PopGroup*** coefficients change. Similarly, the **BasicICT** scores are standardized scores. Test scores are specified linearly; as will be seen in Table 7 this misses an important nonlinearity, but experiments with various specifications find it to be a compact approach to presenting the results that does not appreciably affect the findings of interest. The coefficient γ_1 can be interpreted as the percentage change in hourly wages with a one-standard-deviation increase in basic ICT scores. Equation (2) is estimated on two distinct sub-samples of respondents with valid hourly wages: initially those with an ICT score, and subsequently the entire population employing as regressors those variables at the top of Table 2 indicating why individuals do not have an ICT score. Contrasting across these two regressions allows us to understand the labour market outcomes of those without ICT scores relative to those with them. Of relevance to both models is that the survey design and pre-release data preparation are quite complex (and somewhat opaque). Notably, no individual has a single **BasicICT** score. Rather, everyone has ten individual-specific "plausible values" for PSTRE. These plausible values are designed not to

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personality traits, financial ability (partially helps determine immigration category and location of resident), and non-cognitive skills, could influence differences in basic ICT scores among these individuals.

[8] In additional regressions that are shown in Online Appendix Table OA11 and Table OA12, we used hourly wages that are not recoded. The results remain essentially unchanged.

provide information about individuals, but about the populations they represent. Thus, a jack-knife using the plausible values is employed for inference.[9]

We further look at the sample of individuals with valid hourly wage, regardless whether they have valid basic ICT scores. We separate individuals into six categories: no prior computer experience, failed ICT core test, refused to take computer-based tests, low basic ICT scores (below 241 points), medium basic ICT scores (241 to below 291 points), and high basic ICT scores (291 and above). Other covariates are described as above.

4. Results

4.1 Differences in basic ICT scores between immigrant and Canadian-by-birth categories

In Table 5 we compare ICT scores for different population groups to that of the third generation. Columns (1) and (5) show base OLS results for males and females, respectively, controlling only for age and its square. Consistent with the findings in Table 2, adult immigrants are found to have lower average ICT scores compared to third generation Canadians. Perhaps surprisingly, given the results in Tables 3 and 4 showing that they have higher levels of education, points-based immigrants are more likely to work in jobs requiring complex ICT skills and to live in urban areas, immigrants selected through the points system, by which the principal applicant (most commonly the male for families) is assessed, score about 0.18 for males, and 0.41 for females, standard deviations below those of the same age in the third generation, which is an appreciable gap.[10] All adult immigrants and temporary residents score lower than third-

[9] Please refer to OECD (2013a) on the recommended jack-knife procedure to obtain coefficients and standard errors.

[10] We thank a referee for suggesting that the ICT score deficiency may be concentrated among immigrants not working in jobs using ICT skills. Online Appendix Tables 5 and 6 look at the differences in basic ICT scores in turn for individuals who use a computer, or who use programming and complex ICT skills, at work. The coefficients on the immigration subgroups remain negative, but some are no longer statistically significant at conventional levels. However, the coefficients for points-based immigrants are statistically significantly negative for men and (usually) for women. The ICT skill gap appears to exist in various contexts.

generation Canadians for both males and females. In contrast, young immigrants and Canadians born overseas have point estimates that are positive in three out of four instances, though the coefficients are statistically insignificantly different from zero. This is consistent with Schaafsma and Sweetman (2001) and Hou and Bonikowski (2016) who suggest that young arrivals have, on average, outstanding labour market outcomes. Second generation females score statistically significantly higher than their third-generation counterparts, of the same age.[11]

Adding control variables for highest educational attainment, plus province and rural/urban residence, in columns (2) and (6) of Table 5, increases the magnitude of the gaps for all adult immigrant categories. Immigrants have, on average, not only lower scores controlling just for age but much lower scores relative to the third generation given their education and location of residence.

Columns (3) and (7) introduce a coefficient for having a STEM degree, as well as interactions between the education variables with having received one's highest level of education outside of Canada. Universally, the population sub-group test score gaps narrow relative to the previous columns. The coefficients on foreign-education levels for both genders are negative but statistically insignificant. Recall from Table 3 that just under 75 percent of points-based immigrants completed their highest level of schooling outside of Canada, and the share for all the other groups, except temporary residents, is lower.[12]

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[11] An F-test of the interaction between working in an ICT industry (occupation) and the population subgroups suggests that coefficients on these interaction terms are jointly insignificant. That is, there are no statistically significant differences in the pattern of ICT test scores across population sub-groups for those working in, and outside, these industries (occupations). Of course, this could be partly due to small sample sizes.

[12] Online Appendix Table 7 explores relationships with the countries where the highest education was attained. We group countries of highest education into: Canada, English-speaking countries (UK, USA, Australia, etc.), non-English European countries, East and South-East Asia, the rest of Asia, and other countries (including missing). When country grouping variables are added, the coefficients on the population subgroups remain similar to those in Table 5. However, individuals with foreign education, except for those who obtained their degrees in English-speaking countries, who have higher scores without conditioning on education, now score significantly lower on basic ICT compared to their counterparts who obtained their highest degree in Canada. The difference in basic ICT

Interestingly, males with a Canadian university-level STEM degree and females with college/trade diploma or university degree in STEM have higher ICT scores. The estimates for the interaction of STEM with foreign education are negative, economically large, and statistically significant for males with university education. For females, the point estimates are negative but not statistically significant. Overall, except for males with Canadian STEM diplomas at college/trade level, this seems to suggest that those with Canadian STEM degrees have higher ICT scores than those without such degrees. However, this is, surprisingly, not the case for those with foreign STEM degrees. Foreign university degrees, and particularly those in STEM for men, appear to be associated with appreciably lower basic ICT scores than those with similar Canadian degrees.

Finally, columns (4) and (8) introduce the literacy and numeracy scores as predictors of ICT scores. As noted earlier, the three are highly correlated. Thus, the R-squared for both regressions is substantially higher than for those previously estimated. Adding these two variables renders all other coefficients statistically insignificant for males, except for – quite importantly – the interaction for males who have a foreign university degree in STEM, where the coefficient remains large and statistically significantly negative. Foreign university STEM degree holders appear to have deficits in basic ICT skills that go beyond literacy and numeracy. The relationship for females is somewhat different. The points-based and family reunification category coefficients remain statistically significantly negative, as does the bachelor's coefficient. The pattern of ICT skills is different for males and females; that is not surprising given the evidence in the preceding tables regarding the differing propensity to work in ICT.

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scores between individuals who obtained their education in Canada versus other English-speaking countries is accounted for when we control for level of education. The differences are generally larger for females than males. We also interact level of highest education with the country groupings. However, the sample size is small and the coefficients on most interaction terms are (except for the English-speaking group) negative but not statistically significant.

These results imply that points-based immigrants and those with foreign, especially non-English, university degrees in STEM, appear not be as proficient in using digital technologies to solving problems as the Canadian educated. It is worth recalling that this is part of the OECD's international measurement effort and is not measuring Canada-specific ICT skills. Nevertheless, in the Canadian context, the tests are written in English or French, and the ability to communicate the existence of basic ICT skills may be obscured by English/French language difficulties. Inasmuch as Canadian workplaces rely on knowing English/French, any such skills that are not captured by this measure (should they exist) may not be readily usable in the workplace. Similar to the argument in Warman et al. (2015), language skills may mediate the applicability of other skills. However, there may be situations where workplace communication need not be in English/French, although this likely limits relevant workers' range of job opportunities.

4.2 Earnings gaps with and without controlling for basic ICT scores

4.2.1 Individuals with valid hourly wage and basic ICT scores

Table 6 shows results examining the determinants of (ln) hourly wages by sex. In this analysis, we include in the sample individuals who have valid ICT scores and hourly wages.

The estimates in columns (1) and (5) of Table 6 compare earnings across population categories conditional only on age.[13] Subsequent columns introduce additional controls, and the analysis is, in part, interested in changes in the population gory coefficients across specifications. Controlling only for age, male and female points-based immigrants have comparable hourly wages to those of the third generation. Family reunification and temporary residents have lower

[13] See also Online Appendix Table 8 for similar regressions where the first two specifications have a larger sample size since observations with missing data for regressors used in the final two models are not excluded. A larger number of coefficients are statistically significant.

hourly earnings than the third-generation. For female, additional coefficients are statistically significant.[14]

Columns (2) and (5) add controls for education, including interactions with foreign-education, and for the province and rural/urban residence. The gaps relative to the third generation for points-based males immigrants grow more negative and become statistically significant. This largely reflects the points-based immigrants having higher levels of education. Once controls for education are added, points-based immigrants are expected to have higher earnings.

We introduce basic ICT scores in columns (3) and (7). A one standard deviation increase in ICT scores is associated with about a seven percent increase in wages, with both males and females receiving identical rates of return on ICT skills. Additional specifications akin to columns (3) and (7) introduce interactions of each of the nine population categories with the ICT skills measure. F-tests fail to reject the null hypothesis that the rate of return to ICT skills is the same for all the population groups (p-value = 0.678 for males and 0.720 for females). The labour market also seems to reward these skills at an equal rate for all groups within each sex.

Literacy and numeracy test scores are introduced in columns (4) and (8), for males and females respectively. Of course, these are highly collinear with each other and with the ICT scores. Nevertheless, a one-standard-deviation increase in numeracy scores translates into eight percent and five percent higher in earnings for males and females respectively, even when ICT skills and literacy are taken into account. Numeracy appears to have a strong independent and appreciable impact on earnings. Controlling for all test scores renders all the population group

[14] The online appendix has a larger number of statistically significant results.

coefficients statistically insignificant. However, having foreign education, especially post-secondary education, continues to be associated with lower earnings.[15]

Looking at the education control variables, even with all three test scores in the regression, education, and particularly university education, still affects earnings as does having a STEM diploma at college/trade level for men. The value of higher education goes beyond basic test scores. Almost universally, foreign education seems to have a lower return than that obtained in Canada. Although specified differently, rendering the results not entirely comparable, these results differ qualitatively from some of the earlier literature such as Ferrer, Green and Riddell (2006) who find that test scores explain much of the difference in the rates of return to education for immigrants and the Canadian born.[16]

4.2.2 *Individuals with valid hourly wage, but ICT score may be missing*

Table 7 is similar to Table 6, but it includes respondents who did not write the ICT test and also relaxes the linear specification of ICT scores. We separate individuals into six mutually exclusive and exhaustive categories: no prior computer experience, failed ICT core test, refused to take computer-based tests, and low (below 241 points; the omitted/reference group), medium

[15] In additional regressions, not presented, like columns (2) and (6) of Table 6, we introduce a dummy variable indicating whether an individual works in an ICT industry and interaction terms between this indicator and the immigration classes. Males who work in the ICT industry obtain a 10 percent premium compared to their counterparts in other industries. In contrast, females working in ICT do not enjoy such a premium. These results remain unchanged when controlling for covariates as in columns (3) and (7) or columns (4) and (8). For males, an F-test cannot reject that Canadians and immigrants have the same earnings in the ICT industry (p-values from 0.25 to 0.44 for different specifications). Similarly, for females, p-values range from 0.15 to 0.34 for different specifications. None of the individual coefficients on the interaction terms for females is statistically significant, except for that of young immigrants.

[16] One concern expressed by a referee is that the test scores, and particularly the basic ICT test score, measure skills that are sufficiently basic to have little systematic variation among Canadian university educated workers, and no influence on their earnings. We address this issue in Online Appendix Table 9, which restricts the sample to Canadian and young immigrant workers with exactly a bachelor's degree. For each of the three test scores two regressions are run: first controlling only for age, and a second with a larger set of controls. For all three test scores, in the model controlling only for age the rate of return to each is positive and statistically significant. In each case the coefficient is slightly attenuated with additional control variables, and it becomes statistically insignificant for basic ICT and literacy but remains to significant for numeracy. Overall, we take this as evidence that these measures have some information value even for this small, homogeneous and highly educated sub-group.

(241 to below 291 points), and high (291 and above) basic ICT scores. As in Table 6, the first column for each sex does not control for the education and geographical variables; these covariates are added in columns (2) and (5), and those for literacy and numeracy scores are subsequently included in columns (3) and (6).[17]

In these regressions, those undertaking the basic ICT tests, and scoring in the bottom category, are the base group against which others are compared. In column 1 of Table 7 men who reported no computer experience have the lowest earnings of all six categories and those who refused the preliminary ICT test that would determine whether the computer-based test was feasible have earnings comparable to the lowest scoring group. In contrast, the coefficients for all three reasons for not taking the computer-based test are not statistically significant for women (though the coefficient for those with no computer experience is estimated very imprecisely). That indicates that, for women, the earnings of the three categories of those for whom we do not have an ICT score are on average not statistically different from those in the lowest ICT score category (below 241 points), whereas having no computer experience seems deleterious for men.

The results in Table 7 also suggest that higher than minimum basic ICT scores leads to markedly higher earnings. Interestingly, the ICT coefficients for males and females are broadly similar. Although attenuated compared to the models in columns (1) and (4), the earnings advantage persists when we control for education in columns (2) and (5) and, remarkably, even when we control for both literacy and numeracy skills in columns (3) and (6). The last results contrast with those from Table 6, where the return to basic ICT skills was rendered statistically insignificant by the introduction of literacy and numeracy. We attribute the difference to functional form issues. It seems plausible that there are nonlinearities that cannot be captured in a low order polynomial. Having very low levels of ICT skills is associated with a substantial

[17] See Online Appendix Table 10 for similar specifications but with alternative functional forms.

earnings deficit: if there is a causal link the attainment of quite modest ICT skills would bring appreciable benefits.

Turning to the population subgroup coefficients, for both sexes, the pattern of coefficients in columns (1) and (4) show that most immigrant groups have negative point estimates that are sometimes quite large and statistically significant. However, and in contrast to the earlier results, both points-based and young immigrants now have coefficients that are small and statistically insignificant. Also, except for second-generation female Canadians in the absence of controls, the coefficients for the two Canadian groups included in the regression are not different from the omitted third-generation. The coefficients on education, although somewhat different from those in Table 6, tell a similar story except for university graduates in STEM, where the coefficient is now close to zero and statistically insignificant. Males with foreign degrees, and especially foreign STEM diplomas at the college/trade level, appear to have sizable earnings deficits even after controlling for the various measures of skills.

5. Conclusion

Our paper focuses on the basic ICT skills used in everyday life, rather than advanced ICT skills used by experts, although it is hard to believe that individuals would have advanced skills without these foundational ones. Or, at least highly specialized individuals able to utilize specific advanced ICT skills without basic skills are likely to have few opportunities for advancement and alternatives in the labour market should their current employment end. We look at individual proficiency in ICT in all sectors of the economy, as opposed to just ICT industries and occupations, although we also address those areas. The data suggest that basic ICT skills are broadly valued in the labour market – their reputation as general-purpose technology seems warranted. Higher basic ICT skills are associated with appreciable increases in earnings. Of course, these skills are highly correlated with a range of other skills.

Our data show that male immigrants are disproportionately likely to be working in ITC occupations and industries. Even so, their basic ICT skills are not as great as for the Canadian born. While we can say nothing about the exceptional individuals (industry leaders) in this type of analysis, the broad-based ability to solve problems in the technology-rich environment should be of concern to government and all of society. Our study demonstrates that the labour market rewards basic ICT proficiency equally across immigrant status and sex. However, the data suggest that immigrants educated outside of Canada – even those entering in the points-based class – are, on average, not as proficient in basic ICT skills as third generation Canadians, even after controlling for literacy and numeracy skills. This may be hindering their integration in the labour market. One interpretation of these findings is that adult immigrants would benefit from even minimal levels of basic ICT skills development. Such training might, for example, be built into the curriculum of the language training courses offered to new immigrants. Indeed, all Canadians without such skills would benefit from such training which could be introduced into programs such as those provided by Employment Insurance Part II, perhaps at minimal cost. On the other hand, young immigrants and second-generation immigrants have excellent outcomes that are on par with the third-generation.

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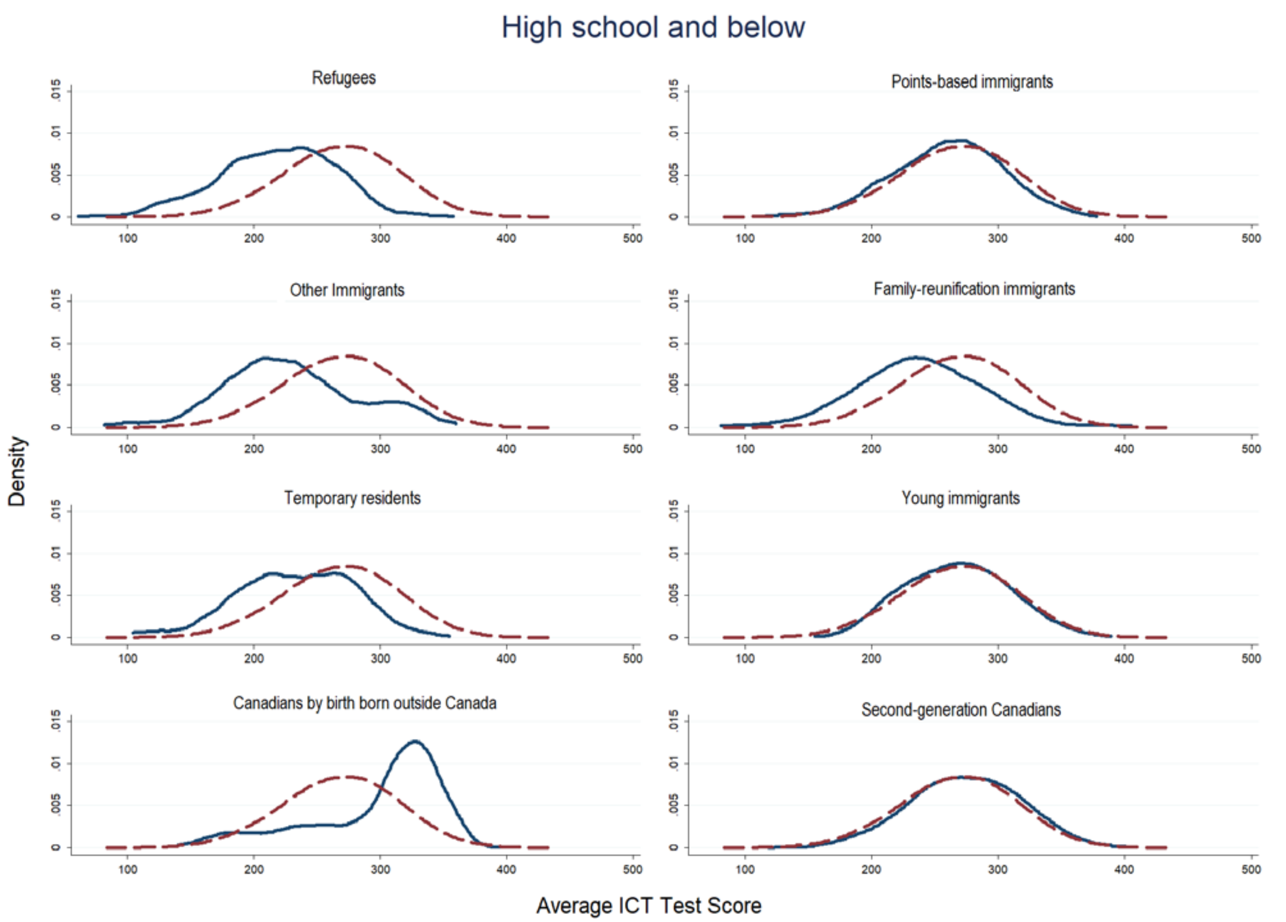
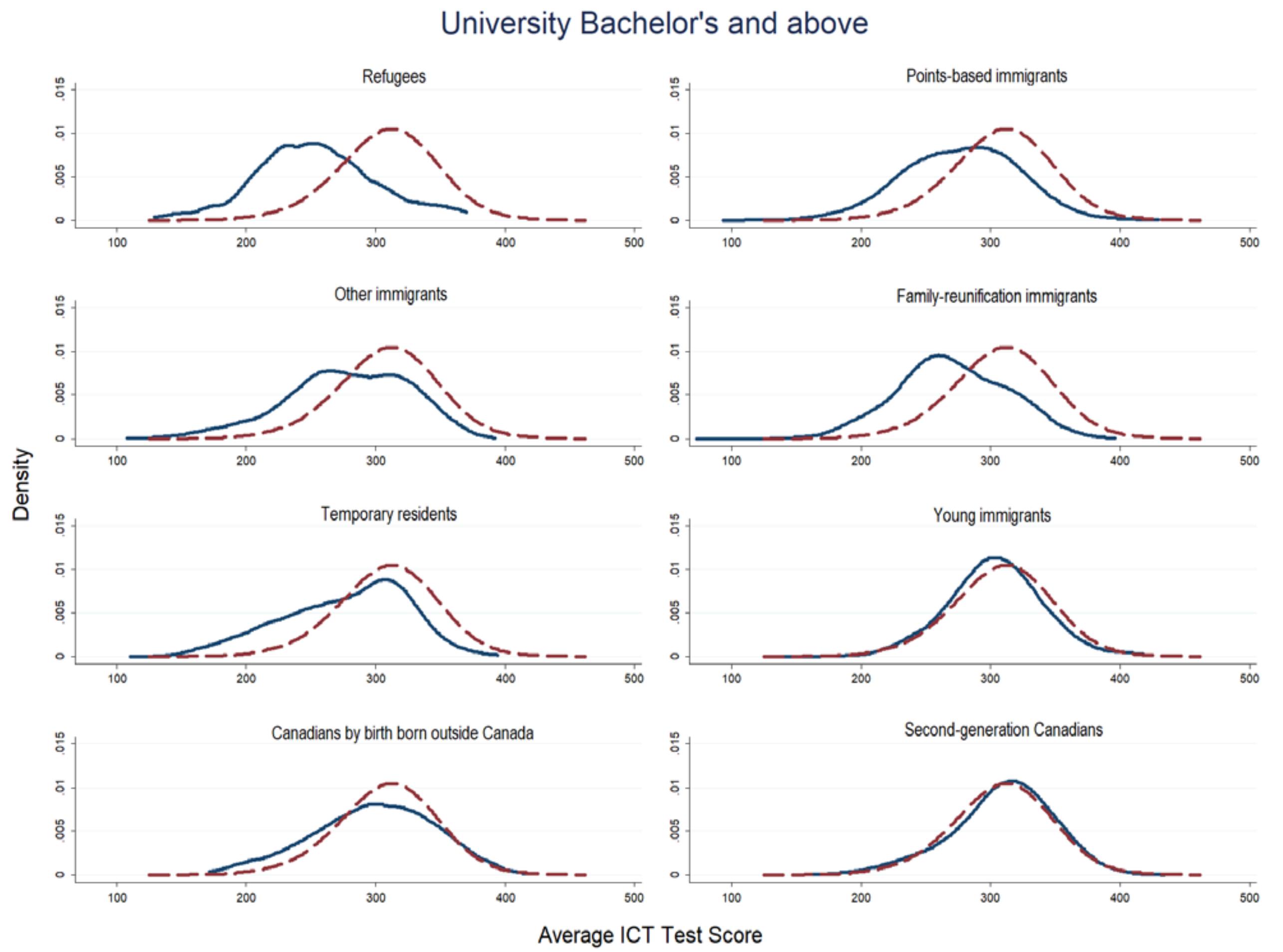
Figure 1. Density plots of basic ICT scores by subpopulation group, without postsecondary education



Source: PIAAC 2012. Authors' calculations.

Note: The dashed line represents the distribution of the test scores for the third generaion. The solid line in each panel represents the distribution of test scores for the respective group named in the title. Each graph is generated using an Epanechnikov kernel with a bandwidth of 12.

Figure 2. Density plots of basic ICT scoresby sub by population group, with university education



Source: PIAAC 2012. Authors' calculations.

Note: The dashed line represents the distribution of the test scores for the third generaion. The solid line in each panel represents the distribution of test scores for the respective group named in the title. Each graph is generated using an Epanechnikov kernel with a bandwidth of 12.

Table 1. Average test scores and employment distribution in ICT occupations and industries

	Male				Female			
	Immigrant		Canadian Born		Immigrant		Canadian Born	
	ICT	Non-ICT	ICT	Non-ICT	ICT	Non-ICT	ICT	Non-ICT
Occupations								
Basic ICT	297.96	271.21	318.45	286.28	292.42	264.86	303.47	286.26
s.d.	41.19	47.34	36.31	44.88	33.19	47.74	34.23	42.72
s.e.	(4.94)	(2.50)	(3.93)	(1.10)	(9.75)	(2.42)	(5.53)	(1.26)
Literacy	294.60	268.45	311.31	287.06	289.29	263.29	301.91	285.47
s.d.	42.12	47.52	37.08	44.99	45.26	47.73	31.60	43.59
s.e.	(5.17)	(2.17)	(4.43)	(1.12)	(12.58)	(2.10)	(4.72)	(1.15)
Numeracy	304.34	271.61	313.47	287.48	285.91	255.23	291.51	272.45
s.d.	43.55	52.67	41.63	48.47	43.11	51.59	35.67	46.62
s.e.	(5.04)	(2.53)	(5.21)	(1.14)	(10.82)	(2.20)	(5.26)	(1.22)
Empl. Distn.-With ICT score (%)	13.67	86.33	5.77	94.23	2.79	97.21	2.31	97.69
Empl. Distn.-All (%)	10.93	89.07	5.17	94.83	2.11	97.89	2.13	97.87
Industries								
Basic ICT	295.40	271.04	310.49	263.78	287.36	285.62	302.43	285.20
s.d.	39.45	47.83	39.48	47.76	39.92	44.96	38.63	42.67
s.e.	(4.48)	(2.50)	(3.64)	(1.08)	(5.63)	(2.54)	(3.22)	(1.29)
Literacy	293.05	268.11	309.28	261.92	288.62	286.12	300.53	284.49
s.d.	41.92	47.66	40.25	47.64	43.27	44.83	37.59	43.67
s.e.	(4.11)	(2.14)	(3.81)	(1.08)	(5.57)	(2.28)	(3.11)	(1.18)
Numeracy	300.08	271.62	309.65	253.73	283.65	286.65	288.80	271.42
s.d.	45.52	52.78	46.62	51.30	47.07	48.14	40.72	46.71
s.e.	(4.60)	(2.65)	(4.03)	(1.18)	(6.75)	(2.35)	(3.52)	(1.32)
Empl. Distn.-With ICT score (%)	15.68	84.32	10.10	89.90	7.86	92.14	8.45	91.55
Empl. Distn.-All (%)	12.73	87.27	9.05	90.95	6.34	93.66	7.93	92.07

Source: PIAAC 2012. Authors' calculations.

Note: ICT occupations and industries defined in Appendix Table A1. Weighted sample of 16,379 for the "all" employment distribution and 13,447 elsewhere. Empl. Distn.=Employment Distribution; s.d.=standard deviation; s.e.=standard error.

Table 2. Percentage of individuals across different levels of basic information and communication technology (ICT) by subpopulation category

	Refugee	**Points-based Immig.**	**Family Reuni-fication**	**Other Immig. Programs**	**Temp. Resident**	**Young Immig.**	**Canadian by birth born outside Canada**	**Second Generation Canadian**	**Third Generation Canadian**
Reason for not taking computer-based tests									
- No compute	11.86	1.4	10.76	2.93	2.91	2.43	4.27	1.02	3.7
- Failed ICT c	15.37	10.23	13.43	8.08	9.06	4.32	1.48	3.59	4.75
- Refused computer-based assessments	11.06	5.8	14.01	7.31	7.04	3.99	8.84	4.11	5.56
Subtotal	38.29	17.43	38.21	18.32	19.01	10.74	14.58	8.72	14.01
Levels of basic ICT test scores									
- Below 241 (l	29.12	19.13	23.29	23.77	26.89	10.6	10.29	9.77	12.94
- 241 to below	25.15	34.93	23.8	27.26	25.09	30.56	20.34	29.68	32.39
- 291 & above	7.44	28.51	14.71	30.65	29.03	48.1	54.79	51.82	40.67
Population sh	1.67	8.08	7.75	1.67	1.98	4.96	1.56	14.94	57.39

Source: PIAAC 2012. Authors' calculations.

Note: These are weighted percentages of 16,379 individuals, aged 22 to 59, for each category of immigrants across different levels of basic ICT scores. Second generation Canadians are individuals who were born in Canada to at least one foreign-born parent. This category excludes Canadians who were born overseas to at least one foreign-born parent. Third generation Canadians are individuals who were born in Canada to Canadian-born parents. Young immigrants are defined as immigrants who arrived aged 12 or younger in all immigration classes. Immigrants in other categories are 13 or older when they arrived in Canada.

Table 3. Average characteristics of individuals by subpopulation category

	Refugee	Points-based Immig.	Family Reuni-fication	Other Immig. Programs	Temporary Resident	Young Immig.	Canadian by birth born outside Canada	Second Generation Canadian	Third Generation Canadian
Average test scores									
Literacy	225.58	267.39	235.31	266.09	242.49	281.96	278.42	290.53	281.78
s.d.	55.59	49.66	55.7	48.96	60.01	48.53	54.23	44.78	46.95
Numeracy	220.27	270.17	223.7	257.53	238.92	273.61	275.53	279.54	274.01
s.d.	56.7	55.25	61.17	53.22	66.42	55.32	59.4	51.56	51.32
Basic ICT	242.29	273.08	256.88	267.71	262.85	290.63	295.38	293.23	285.56
s.d.	45.22	44.44	46.82	50.56	52.23	42.55	45.49	42.09	44.12
Demographic characteristics									
Average hourly wage	21.77	29.23	21.48	23.16	20.83	30.28	26.46	29.4	28.16
Average age	44.48	42.6	42.15	42.41	33.33	38.54	39.8	39.94	41.46
Average age at immigration	28.31	31.29	25.38	26.54	27.8	6.02	12.76	n/a	n/a
Proportion of male	0.63	0.54	0.42	0.47	0.48	0.49	0.5	0.51	0.51
Proportion living in									
- small urban population center	0.01	0.02	0.02	0.04	0.03	0.06	0.06	0.1	0.16
- medium urban population center	0.03	0.03	0.02	0.04	0.03	0.04	0.07	0.08	0.12
- large urban population center	0.96	0.93	0.93	0.84	0.93	0.85	0.76	0.67	0.49
Education characteristics									
- Below HS	12.18	3.6	18.09	9.05	12.4	5.7	10.94	6.45	11.25
- HS	26.15	8.98	23.37	11.71	22.7	17.1	23.56	20.85	22.79
- College/Trade (C/T)	36.71	22.41	27.87	33.68	21.41	39.8	34.91	41.26	41.84
- Bachelor's and above	24.97	65.01	30.67	45.58	43.49	37.39	30.6	31.44	24.13
Proportion STEM, college/trades	0.17	0.08	0.12	0.08	0.11	0.13	0.16	0.13	0.14
Proportion STEM Bach. & above	0.05	0.31	0.09	0.14	0.18	0.10	0.08	0.07	0.05
Proportion with foreign education	0.65	0.74	0.72	0.69	0.83	0.07	0.25	0.02	0.01
Population shares	1.67	8.08	7.75	1.67	1.98	4.96	1.56	14.94	57.39

Source: PIAAC 2012. Authors' calculations.

Note: These are weighted percentages and means for 16,379 individuals from 22 to 59 years old, by immigration category. Average test scores are calculated using all plausible values and replicate weights available in PIAAC. Average ICT scores are calculated for sub-sample of individuals who attempted the computer-based assessments. A small urban population center has a population of 1,000 to 29,999 habitants. A medium urban population center has a population of 30,000 to 99,999 habitants. A large urban population center has a population of 100,000 habitants or greater. Average hourly wages are calculated for individuals who self-reported positive earnings at the time of survey.

Table 4. Probability of ICT used at work for individuals employed at time of survey

	OLS - Dependent variable: Probability of							
	Using computer at work[1]	Email[2]	Excel[3]	Word[4]	Programming[5]	Complex ICT Skills[6]	Sufficient ICT Skills[7]	Lack of ICT Skills[8]
Male								
Points-based immigrants	0.132***	0.045	0.096**	0.119***	0.153***	0.115***	0.023	0.137***
	(0.023)	(0.025)	(0.032)	(0.026)	(0.034)	(0.030)	(0.016)	(0.029)
Refugee/Family Reunification Immigrants	-0.138***	-0.173***	-0.187***	-0.166***	0.017	0.029	-0.078*	0.105**
	(0.037)	(0.043)	(0.048)	(0.045)	(0.037)	(0.036)	(0.037)	(0.033)
Other Immigrants/Temporary Residents (Temp. Res.)	-0.059	-0.031	-0.000	0.060	0.083	0.126*	0.030**	0.054
	(0.062)	(0.055)	(0.059)	(0.050)	(0.055)	(0.064)	(0.011)	(0.043)
Young Immigrants	0.099*	0.001	0.082	0.094*	0.063	0.097	-0.013	0.010
	(0.044)	(0.049)	(0.051)	(0.044)	(0.049)	(0.051)	(0.033)	(0.024)
Second Generation	0.077**	0.050*	0.044	0.076**	0.035	-0.005	0.009	0.018
	(0.025)	(0.023)	(0.032)	(0.027)	(0.030)	(0.019)	(0.017)	(0.017)
Female								
Points-based immigrants	-0.034	-0.021	-0.120**	-0.060	-0.148***	-0.147***	-0.047	0.019
	(0.031)	(0.036)	(0.046)	(0.041)	(0.039)	(0.032)	(0.033)	(0.047)
Refugee/Family Reunification Immigrants	-0.023	0.103	0.027	0.107	-0.081	-0.092*	0.061	0.056
	(0.054)	(0.055)	(0.058)	(0.060)	(0.043)	(0.045)	(0.038)	(0.045)
Other Immigrants/Temp. Res.	0.058	-0.055	-0.218**	-0.227**	-0.130	-0.175*	-0.007	0.037
	(0.075)	(0.090)	(0.080)	(0.079)	(0.071)	(0.070)	(0.020)	(0.066)
Young Immigrants	0.023	0.089	-0.132	0.047	-0.154**	-0.142*	0.008	0.036
	(0.048)	(0.059)	(0.072)	(0.058)	(0.054)	(0.055)	(0.039)	(0.047)
Second Generation	0.083**	0.017	-0.029	0.028	-0.112***	-0.062**	0.010	-0.002
	(0.028)	(0.025)	(0.044)	(0.028)	(0.033)	(0.022)	(0.017)	(0.022)
Third Generation	0.125***	0.028*	-0.029	0.055**	-0.089***	-0.062***	0.007	0.017*
	(0.014)	(0.013)	(0.020)	(0.018)	(0.015)	(0.012)	(0.008)	(0.008)
Age - 40	0.037***	0.024***	0.040***	0.026***	0.014**	0.013***	0.003	0.007
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.003)	(0.003)	(0.004)
$(Age - 40)^2/100$	-0.046***	-0.028***	-0.049***	-0.032***	-0.021***	-0.018***	-0.007	-0.009

	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.004)	(0.004)	(0.005)
Constant	0.795***	0.882***	0.775***	0.782***	0.189***	0.129***	0.951***	0.057***
	(0.013)	(0.013)	(0.016)	(0.015)	(0.014)	(0.011)	(0.007)	(0.007)
N	11072	8694	8689	8693	8689	8687	8692	8681
R^2	0.060	0.027	0.029	0.029	0.046	0.040	0.024	0.032
Adjusted R^2	0.059	0.025	0.028	0.028	0.044	0.038	0.022	0.031

Note: * p<0.05, ** p<0.01, *** p<0.001

Standard errors are in parentheses.

The overall sample includes 16,379 individuals, aged 22-59. In each column, we control for standardized age and its quadratic form (Age-40 and $(\text{Age-}40)^2/100$). We only include individuals who are currently employed at the time of survey. However, we have dropped individuals who have missing information for each respective column. Ordinary least squares method was employed to calculate point estimates using all given plausible values of basic ICT scores in PIAAC 2012. Each column corresponds to each of the following survey questions:

1. Do you use a computer in your current job? (1 – Yes, and 0 – No)
2. In your current job, how often do you usually use email? (1 – some usage of email (from less than once a month to every day), and 0 – never used)
3. In your current job, how often do you usually use spreadsheets software, for example, Excel? (1 – some usage of Excel (from less than once a month to every day), and 0 – never used)
4. In your current job, how often do you usually use a word processor, for example, Word? (1 – some usage of Word (from less than once a month to every day), and 0 – never used)
5. In your current job, how often do you usually use a programming language to program or write computer code? (1 – some usage of programming language (from less than once a month to every day), and 0 – never used)
6. What level of computer use was needed to perform your current job? (1 – for individuals who answered “complex, and 0 – for everyone else (straightforward and moderate))
7. Do you think you have the computer skills you need to perform your current job well? (1 – Yes, and 0 – everyone else)
8. Has a lack of computer skills affected your chances of being hired for a job or getting a promotion or a pay raise? (1 – Yes, and 0 – everyone else)

Table 5. Determinants of basic ICT scores, for individuals with positive self-reported earnings

	Dependent variable: Basic ICT scores							
	Male				Female			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Literacy				0.614***				0.590***
				(0.032)				(0.028)
Numeracy				0.229***				0.230***
				(0.036)				(0.030)
Points-based immigrants	-0.180*	-0.547***	-0.421***	-0.032	-0.413***	-0.566***	-0.532***	-0.207*
	(0.078)	(0.080)	(0.116)	(0.089)	(0.097)	(0.094)	(0.123)	(0.094)
Refugee	-0.717**	-0.797***	-0.756**	-0.067	-1.220***	-1.238***	-1.208***	-0.359
	(0.252)	(0.242)	(0.255)	(0.160)	(0.283)	(0.301)	(0.341)	(0.195)
Other immigration program	-0.022	-0.269	-0.239	0.015	-0.455**	-0.555***	-0.493**	-0.139
	(0.210)	(0.215)	(0.190)	(0.144)	(0.164)	(0.162)	(0.176)	(0.154)
Family reunification	-0.551***	-0.667***	-0.594***	0.015	-0.813***	-0.875***	-0.822***	-0.240*
	(0.125)	(0.121)	(0.137)	(0.087)	(0.115)	(0.104)	(0.118)	(0.098)
Temporary residents	-0.338	-0.506*	-0.356	0.090	-0.924***	-0.964***	-0.907***	-0.290
	(0.205)	(0.199)	(0.193)	(0.146)	(0.227)	(0.217)	(0.248)	(0.163)
Young immigrants	0.050	-0.048	-0.116	0.077	-0.036	-0.114	-0.186	-0.004
	(0.134)	(0.134)	(0.140)	(0.105)	(0.121)	(0.119)	(0.123)	(0.103)
Canadians by birth born outside Canada	0.180	0.095	0.030	0.061	0.127	0.054	0.017	0.008
	(0.208)	(0.241)	(0.231)	(0.154)	(0.188)	(0.184)	(0.184)	(0.174)
Second generation Canadians	0.130	0.074	0.010	0.059	0.168**	0.103	0.038	0.008
	(0.066)	(0.065)	(0.070)	(0.044)	(0.064)	(0.061)	(0.063)	(0.043)
Age	0.030	0.005	0.016	-0.006	0.049**	0.021	0.025	0.003
	(0.019)	(0.017)	(0.017)	(0.013)	(0.019)	(0.018)	(0.018)	(0.016)
$Age^2/100$	-0.059*	-0.030	-0.043*	-0.007	-0.088***	-0.049*	-0.053*	-0.020
	(0.024)	(0.022)	(0.021)	(0.016)	(0.023)	(0.022)	(0.022)	(0.019)
Education								
Below HS		-0.762***	-1.028*	-0.405		-0.724***	-0.528	-0.173
		(0.113)	(0.463)	(0.425)		(0.120)	(0.337)	(0.377)
College/Trade (C/T)		0.208**	0.149	-0.023		0.145*	0.126	-0.056
		(0.071)	(0.101)	(0.058)		(0.057)	(0.065)	(0.054)
Bachelor's and above (Bach. & above)		0.718***	0.576***	-0.134		0.542***	0.510***	-0.139*

		(0.072)	(0.090)	(0.076)		(0.058)	(0.060)	(0.059)
C/T graduates with STEM degree			0.080	-0.006			0.269**	0.096
			(0.090)	(0.056)			(0.102)	(0.076)
Bach. & above graduates with STEM degree			0.323***	0.140			0.305**	0.060
			(0.096)	(0.075)			(0.113)	(0.081)
Individuals with missing fields of study			0.303	0.281			-0.173	0.039
			(0.440)	(0.414)			(0.337)	(0.381)
Interaction								
Below HS x Foreign education			-0.884	-0.664			-0.160	-0.038
			(1.062)	(0.653)			(0.486)	(0.253)
HS x Foreign education			-0.509	-0.118			-0.313	0.041
			(0.261)	(0.205)			(0.208)	(0.159)
C/T x Foreign education			-0.415*	-0.193			-0.133	0.025
			(0.207)	(0.156)			(0.167)	(0.128)
Bach. & above x Foreign education			-0.057	0.041			-0.238*	0.063
			(0.144)	(0.099)			(0.121)	(0.083)
C/T STEM degree x Foreign education			0.317	0.170			-0.690	-0.169
			(0.268)	(0.193)			(0.687)	(0.380)
Bach. & above STEM degree x Foreign education			-0.495**	-0.270*			-0.139	0.002
			(0.171)	(0.128)			(0.185)	(0.135)
Missing field of study x Foreign education			n/a	n/a			n/a	n/a
			n/a	n/a			n/a	n/a
Other covariates:								
- Provinces	N	Y	Y	Y	N	Y	Y	Y
- Rural/urban indicators	N	Y	Y	Y	N	Y	Y	Y
Constant	-0.079	0.209	0.138	0.439	-0.364	-0.101	-0.079	0.370
	(0.359)	(0.331)	(0.314)	(0.246)	(0.373)	(0.354)	(0.357)	(0.291)
N	4434	4434	4434	4434	5109	5109	5109	5109
R^2	0.073	0.208	0.236	0.725	0.15	0.24	0.268	0.718
Adjusted R^2	0.071	0.206	0.23	0.723	0.149	0.239	0.263	0.716

Note: * p<0.05, ** p<0.01, *** p<0.001
Standard errors are in parentheses.
The analysis was done separately for each gender. Ordinary least squares method was employed to calculate point estimates using all given plausible values of basic ICT test scores in PIAAC 2012. Only males and females with valid basic ICT test scores and positive self-reported earnings were included in the above table. All replicate weights were employed to derive standard errors following the delete-one jackknife method outlined in OECD (2013a). The omitted group is third generation Canadians, who live in large urban population centers in Ontario, and obtained a HS diploma as the highest educational attainment in Canada.

Table 6. Determinants of log hourly wage

	Dependent variable: Log(Hourly Wage)							
	Male				Female			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Literacy				0.001				0.026
				(0.033)				(0.029)
Numeracy				0.082***				0.050*
				(0.024)				(0.025)
Basic ICT			0.072***	0.013			0.073***	0.018
			(0.013)	(0.022)			(0.012)	(0.025)
Points-based immigrants	-0.037	-0.137*	-0.106*	-0.100	-0.041	-0.062	-0.024	-0.028
	(0.033)	(0.054)	(0.054)	(0.054)	(0.043)	(0.055)	(0.054)	(0.055)
Refugee	-0.198	-0.192	-0.137	-0.118	-0.299**	-0.260**	-0.172	-0.164
	(0.106)	(0.102)	(0.099)	(0.094)	(0.115)	(0.088)	(0.097)	(0.102)
Other immigration program	-0.238	-0.310	-0.293	-0.276	-0.118**	-0.107	-0.072	-0.066
	(0.153)	(0.182)	(0.184)	(0.180)	(0.045)	(0.060)	(0.060)	(0.061)
Family reunification	-0.182***	-0.175**	-0.132*	-0.106	-0.199***	-0.155**	-0.095	-0.089
	(0.052)	(0.057)	(0.059)	(0.057)	(0.050)	(0.060)	(0.058)	(0.058)
Temporary residents	-0.210*	-0.225	-0.199	-0.175	-0.298***	-0.241*	-0.175	-0.170
	(0.100)	(0.115)	(0.115)	(0.113)	(0.080)	(0.110)	(0.103)	(0.101)
Young immigrants	0.111	0.060	0.068	0.086	0.093	0.017	0.031	0.037
	(0.061)	(0.069)	(0.067)	(0.065)	(0.054)	(0.051)	(0.052)	(0.051)
Canadians by birth born outside Canada	-0.009	-0.067	-0.070	-0.073	0.062	-0.010	-0.012	-0.014
	(0.104)	(0.091)	(0.088)	(0.088)	(0.091)	(0.088)	(0.088)	(0.090)
Second generation Canadians	0.006	-0.051	-0.051	-0.042	0.093**	0.021	0.018	0.018
	(0.039)	(0.039)	(0.040)	(0.039)	(0.029)	(0.027)	(0.026)	(0.026)
Age	0.085***	0.074***	0.073***	0.072***	0.085***	0.070***	0.068***	0.068***
	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)	(0.007)	(0.007)	(0.007)
$Age^2/100$	-0.087***	-0.074***	-0.071***	-0.071***	-0.094***	-0.073***	-0.069***	-0.069***
	(0.011)	(0.010)	(0.010)	(0.010)	(0.011)	(0.009)	(0.009)	(0.009)
Education								
Below HS		-0.225	-0.151	-0.166		-0.428**	-0.390*	-0.386**
		(0.261)	(0.255)	(0.270)		(0.142)	(0.153)	(0.148)
College/Trade (C/T)		0.042	0.031	0.025		0.165***	0.156***	0.147***

		(0.042)	(0.042)	(0.043)		(0.029)	(0.028)	(0.028)
Bachelor's and above (Bach. & above)		0.397***	0.356***	0.323***		0.466***	0.429***	0.398***
		(0.041)	(0.043)	(0.045)		(0.032)	(0.032)	(0.034)
C/T graduates with STEM degree		0.179***	0.174***	0.160***		0.027	0.007	0.001
		(0.035)	(0.034)	(0.034)		(0.049)	(0.049)	(0.049)
Bach. & above graduates with STEM degree		0.058	0.035	0.024		0.051	0.029	0.017
		(0.042)	(0.043)	(0.042)		(0.053)	(0.054)	(0.055)
Individuals with missing fields of study		0.128	0.106	0.134		0.299*	0.311*	0.319*
		(0.262)	(0.254)	(0.271)		(0.141)	(0.151)	(0.146)
Interaction								
Below HS x Foreign education		-0.376	-0.312	-0.368		-0.027	-0.015	-0.013
		(0.389)	(0.421)	(0.406)		(0.144)	(0.163)	(0.168)
HS x Foreign education		-0.155*	-0.118	-0.111		-0.179*	-0.156*	-0.143
		(0.075)	(0.077)	(0.078)		(0.075)	(0.074)	(0.074)
C/T x Foreign education		0.043	0.073	0.065		-0.199*	-0.189*	-0.180*
		(0.098)	(0.098)	(0.102)		(0.088)	(0.085)	(0.087)
Bach. & above x Foreign education		-0.170**	-0.166**	-0.162*		-0.296***	-0.279***	-0.264***
		(0.064)	(0.063)	(0.063)		(0.071)	(0.071)	(0.070)
C/T STEM degree x Foreign education		-0.226	-0.249	-0.246		0.088	0.138	0.145
		(0.134)	(0.131)	(0.133)		(0.112)	(0.138)	(0.139)
Bach. & above STEM degree x Foreign education		-0.009	0.027	0.018		0.035	0.045	0.049
		(0.088)	(0.088)	(0.086)		(0.089)	(0.088)	(0.088)
Missing field of study x Foreign education		n/a	n/a	n/a		-0.086	n/a	n/a
		n/a	n/a	n/a		(0.394)	n/a	n/a
Other covariates:								
- Provinces	N	Y	Y	Y	N	Y	Y	Y
- Rural/urban indicators	N	Y	Y	Y	N	Y	Y	Y
Constant	1.383***	1.482***	1.472***	1.496***	1.319***	1.378***	1.383***	1.425***
	(0.174)	(0.164)	(0.162)	(0.163)	(0.170)	(0.145)	(0.146)	(0.147)
N	4434	4434	4434	4434	5109	5109	5109	5109
R^2	0.117	0.271	0.283	0.292	0.101	0.284	0.293	0.3
Adjusted R^2	0.116	0.266	0.277	0.286	0.099	0.279	0.288	0.295

Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard errors are in parentheses.
The analysis was done separately for male and female. Ordinary least squares method was employed to calculate point estimates using all given plausible values of basic ICT scores in PIAAC 2012. Only males and females with valid basic ICT test scores and positive self-reported earnings were included in the above table. All replicate weights were employed to derive standard errors following the delete-one jackknife method outlined in OECD (2013a).
Income of the top 0.05% is set to be equal to CAD 112.98 per hour. The omitted group is third generation Canadians, who live in large urban population centers in Ontario, and obtained a HS diploma as the highest educational attainment in Canada.

Table 7. Determinants of log hourly wage, including individuals with no basic ICT scores

	Dependent variable: Log(Hourly Wage)					
	Male			Female		
	(1)	(2)	(3)	(4)	(5)	(6)
Literacy			-0.005			0.027
			(0.025)			(0.024)
Numeracy			0.078***			0.043
			(0.022)			(0.024)
Reasons for not taking computer-based tests						
No computer experience	-0.263***	-0.182***	-0.160**	-0.194	-0.071	-0.078
	(0.053)	(0.053)	(0.053)	(0.102)	(0.106)	(0.106)
Failed ICT core tests	0.097*	0.052	0.032	0.003	-0.029	-0.052
	(0.047)	(0.044)	(0.042)	(0.049)	(0.046)	(0.044)
Refused taking computer-based tests	-0.010	0.026	-0.008	-0.034	-0.033	-0.078
	(0.046)	(0.040)	(0.046)	(0.044)	(0.039)	(0.042)
Levels of basic ICT test scores						
241 points to < 291 points	0.220***	0.159***	0.101***	0.174***	0.109***	0.054
	(0.028)	(0.027)	(0.030)	(0.031)	(0.027)	(0.031)
291 points and above	0.361***	0.219***	0.102**	0.365***	0.201***	0.090*
	(0.030)	(0.031)	(0.039)	(0.031)	(0.030)	(0.040)
Points-based immigrants	-0.003	-0.086	-0.079	0.005	-0.060	-0.056
	(0.031)	(0.046)	(0.046)	(0.039)	(0.052)	(0.052)
Refugee	-0.216***	-0.191**	-0.155*	-0.204*	-0.224***	-0.196**
	(0.065)	(0.068)	(0.068)	(0.091)	(0.066)	(0.071)
Other immigration program	-0.212	-0.247	-0.228	-0.070	-0.093	-0.083
	(0.151)	(0.176)	(0.172)	(0.051)	(0.064)	(0.066)
Family reunification	-0.190***	-0.182***	-0.144**	-0.094*	-0.116*	-0.094
	(0.040)	(0.053)	(0.053)	(0.039)	(0.051)	(0.052)
Temporary residents	-0.182*	-0.191	-0.159	-0.227***	-0.246**	-0.224**
	(0.083)	(0.104)	(0.105)	(0.063)	(0.089)	(0.086)
Young immigrants	0.096	0.060	0.081	0.081	0.012	0.020
	(0.057)	(0.063)	(0.061)	(0.049)	(0.047)	(0.047)
Canadian born overseas	-0.072	-0.095	-0.094	-0.004	-0.050	-0.039
	(0.093)	(0.081)	(0.082)	(0.086)	(0.082)	(0.082)
Second generation Canadians	0.003	-0.043	-0.036	0.074**	0.018	0.018

	(0.036)	(0.037)	(0.037)	(0.027)	(0.026)	(0.026)
Age	0.079***	0.072***	0.071***	0.073***	0.065***	0.065***
	(0.008)	(0.008)	(0.007)	(0.008)	(0.007)	(0.007)
$Age^2/100$	-0.078***	-0.070***	-0.070***	-0.076***	-0.065***	-0.065***
	(0.010)	(0.009)	(0.009)	(0.010)	(0.009)	(0.009)
Education						
Below HS		-0.110	-0.129		-0.252	-0.257
		(0.211)	(0.211)		(0.202)	(0.192)
College/Trade (C/T)		0.031	0.027		0.168***	0.158***
		(0.039)	(0.041)		(0.026)	(0.026)
Bachelor's and above (Bach. & above)		0.356***	0.323***		0.443***	0.408***
		(0.040)	(0.042)		(0.031)	(0.031)
C/T graduates with STEM degree		0.172***	0.156***		0.015	0.004
		(0.032)	(0.032)		(0.047)	(0.048)
Bach. & above graduates with STEM degree		0.058	0.039		0.032	0.018
		(0.040)	(0.040)		(0.053)	(0.054)
Individuals with missing fields of study		0.044	0.088		0.160	0.187
		(0.211)	(0.212)		(0.206)	(0.195)
Interaction						
Below HS x Foreign education		0.011	0.043		0.063	0.107
		(0.097)	(0.101)		(0.420)	(0.475)
HS x Foreign education		-0.105	-0.081		-0.033	-0.017
		(0.061)	(0.062)		(0.068)	(0.071)
C/T x Foreign education		0.049	0.042		-0.164*	-0.153*
		(0.091)	(0.093)		(0.073)	(0.075)
Bach. & above x Foreign education		-0.213***	-0.210***		-0.289***	-0.273***
		(0.059)	(0.059)		(0.064)	(0.063)
C/T STEM degree x Foreign education		-0.248*	-0.238*		0.024	0.045
		(0.118)	(0.118)		(0.127)	(0.134)
Bach. & above STEM degree x Foreign education		0.041	0.045		0.073	0.079
		(0.080)	(0.079)		(0.083)	(0.082)
Missing field of study x Foreign education		n/a	n/a		-0.057	-0.068
		n/a	n/a		(0.401)	(0.457)

Other covariates:						
- Provinces	N	Y	Y	N	Y	Y
- Rural/urban indicators	N	Y	Y	N	Y	Y
Constant	1.216***	1.350***	1.446***	1.235***	1.313***	1.418***
	(0.164)	(0.157)	(0.155)	(0.160)	(0.145)	(0.148)
N	5254	5254	5254	5816	5816	5816
R^2	0.193	0.294	0.305	0.18	0.305	0.313
Adjusted R^2	0.190	0.289	0.299	0.177	0.300	0.308

Note: * p<0.05, ** p<0.01, *** p<0.001
Standard errors are in parentheses.
The analysis was done separately for male and female. Ordinary least squares method was employed to calculate point estimates using all given plausible values of basic ICT scores in PIAAC 2012. All replicate weights were employed to derive standard errors following the delete-one jackknife method outlined in OECD (2013a). The sample includes individuals, aged 22 to 59, who self-reported positive earnings at the time of survey. Income of the top 0.5% is set to be equal to CAD 112.98 per hour. The omitted group is third generation Canadians, who live in large urban population center in Ontario, obtained a HS diploma as the highest educational attainment in Canada, and belong to the lowest group of ICT scores (below 241 points).

Appendix Table A1. The list of 15 core digital economy occupations defined by ICTC and ICT industries

Definition	Description
ICT Industries	
NAICS 2012	
51	Information and cultural industries
54	Professional, scientific and technical services
ICT Occupations	15 digital economy occupations defined by ICTC (2016a)
NOC 2011	
0131	Telecommunication carrier managers
0213	Computer and information system managers
2133	Electrical and electronics engineers
2147	Computer engineers
2171	Information systems analysts and consultants
2172	Database analysts and data administrators
2173	Software engineers
2174	Computer programmers and interactive media developers
2175	Web designers and developers
2241	Electrical and electronics engineering technologists and technicians
2281	Computer network technicians
2282	User support technicians
2283	Systems testing technicians
5224	Broadcast technicians
5241	Graphic designers and illustrators

Note:

NAICS 2012 = The North American Industry Classification System (NAICS) Canada 2012

NOC 2011 = The National Occupational Classification 2011