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Abstract

It is well-established that human capital contributes to unequal levels of earnings mobility. Individuals with higher levels of human capital, typically measured through education, earn more on average and are privy to greater levels of upward change over time. Nevertheless, other factors may have an incremental effect over education, namely cognitive ability and the skill demands of employment. To deepen insight into whether these aspects contribute to earnings mobility over a four-year period, the present study examines positional change in Canada and Germany—two contexts typified as examples of liberal and coordinated market economies. A series of descriptive indices and relative change models assess how different measures of human capital are associated with earnings mobility. The results indicate that, while individuals with higher cognitive skills experience greater earnings stability and upward mobility in both countries, there is only an incremental effect of skills on mobility in Germany once we account for educational credentials. The results also provide evidence on the role of skill demands for earnings mobility; in both countries, advanced skills at work are associated with greater short-term mobility, even while controlling for cognitive ability and other factors. Together the results showcase how longitudinal data containing detailed measures of human capital allow for deeper insight into what facilitates earnings mobility.

Keywords: Earnings mobility, Human capital, PIAAC, Relative income position, Cognitive skills

JEL: I24, I26, J24, J31

1 Background

Over the past decades, earnings inequality has increased in many countries, including Canada and Germany. In Canada, inequality grew over the 1980s, especially at the top of the earnings distribution (Green et al. 2017). Until the early 1990s, the increase in earnings inequality in Germany was limited to the upper end of the earnings distribution but has continued steadily at both the upper and lower ends thereafter (Fitzenberger 1999; Dustmann et al. 2009; Antonczyk et al. 2012; Grabka

and Goebel 2017; Bartels 2019). Earnings mobility is not only an important aspect of economic security and well-being but also a factor that either increases or decreases overall earnings inequality at the societal level. Because it may contribute to convergence and greater equalization (Friedman 1962) or generate inequality through divergence and unequal change (Raferzeder and Winter-Ebmer 2007), there is a need to understand which factors contribute to upward or downward mobility. Many factors are at the societal, economic, or policy level, such as economic downturn, while others encompass employment or individual characteristics (Choi 2016; Garnero et al. 2019).

With a focus on individual characteristics, human capital theory suggests that "the ability to deal successfully with economic disequilibria is enhanced by education"

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(Schultz 1975, 843) and "steepens age-earnings profiles" (Becker 1962, 29). In this sense, human capital is deemed to provide greater adaptability, ability, and/or opportunity to favorably navigate changing economic circumstances in ways that lead to positive earnings mobility. Yet, as signaling (Spence 1974) and cognitive psychology (Peng and Kievit 2020) theory and research suggests, there may be separate, confounding, or bidirectional relationships among education credentials and cognitive skills. Although cognitive skills generally increase with higher education levels, they also vary at each level (OECD 2013a); as an example, not all individuals with a bachelor's degree have higher cognitive skill levels compared to those who only hold a high school diploma. In short, the study of cognitive skills may capture aspects of human capital not acquired within the school context and, thus, not reflected in educational credentials. In this sense, cognitive skills may become more relevant for earnings and earnings mobility over the course of an individual's working life (Altonji and Pierret 2001). Higher credentials may also provide opportunities for earnings mobility through access to jobs with specific characteristics, such as employment with higher skill use and demand, factors that are also associated with cognitive skills (OECD 2013a).

Using data from the Canadian and German longitudinal components of the Programme for the International Assessment of Adult Competencies (PIAAC), the present study enhances our understanding of the associations between earnings mobility and cognitive skills, skill use and demands in employment, as well as educational credentials. A comparison between Germany and Canada provides insight into if and how these associations vary in two distinct contexts. As will be discussed further in the literature review, Germany and Canada differ in many respects, especially in terms of their level of labour market regulation and educational systems. Germany is typically identified as a coordinated market economy that promotes job-specific skills, while Canada is recognized as a liberal market economy that promotes general skill acquisition (Estevez-Abe et al. 2001). By adding a comparative component, this study provides insight into if and how the relationship between earnings mobility and human capital differs or is similar across varying contexts.

This study answers three primary research questions: *To what extent do individual differences in cognitive skills contribute to differences in short-term earnings mobility? How does accounting for skill use and demands at work, education, and additional individual characteristics change this association? And finally, how do the trends observed differ between Canada and Germany?* Studying short-term mobility over a four-year period, we estimate two types of analysis: a series of descriptive mobility and inequality indices; and multivariate linear regression models that measure change in the relative position of individuals between 2012 and 2016 in the within-country distribution of earnings. Rather than isolate the impact of a particular feature of either country, our comparative case study approach aims to provide a rich picture of the associations among earnings mobility, cognitive skills, job characteristics, and credentials in each context.

2 Earnings mobility and human capital

"Intraindividual" mobility measures change in earnings among the same individuals over time (Shorrocks 1978). Also termed "intragenerational" mobility, research in this area examines dynamic positional change (e.g., change in an individual's position in the earnings distribution), individual growth (e.g., measures of trajectories of change over time), long-term inequality (e.g., average earnings and period-specific deviations), or risk (e.g., earnings instability) (Jäntti and Jenkins 2015). A large body of research on mobility also examines earnings growth and variance over time using cross-sectional data, often with the aim of decomposing permanent and transitory variance (e.g., Gottschalk and Moffitt 2009). The present contribution, however, focuses specifically on short-term mobility over a four-year period among the same individuals as measured by upward or downward positional change in earnings percentiles.

A positional change signals increased or decreased earnings relative to others. There would be no positional change if all earnings among a group of people increased or decreased to the same extent. Rather, positive change takes place when only certain people experience an increase in earnings (e.g., upward movement from the 50th to the 60th percentile) and negative change takes place when other people experience a decrease in earnings (e.g., downward movement from the 60th to the 50th percentile). Some forms of positional change are associated with employment trajectories over the life course, such as early-career increases or late-career decreases in earnings (e.g., Raferzeder and Winter-Ebmer 2007). Employment transitions (i.e., change in hours or position) may also result in a positional change in earnings (e.g., Kosteas 2009). Unlike an approach that measures change in real earnings over time, a positional change approach provides greater insight into the "incidence, intensity and inequality of positional mobility" (Creedy and Gemmell 2019, 753).

When it comes to the determinants of positional change, human capital is seen as a key driver. Research demonstrates that individuals with higher levels of education experience more upward mobility in their prime age working years (Heckman et al. 1998; Connolly and

Gottschalk 2006) and less variation in earnings during economic downturns (Rauscher and Elliott 2016). Using Austrian data between 1994 and 2001, Raferzeder and Winter-Ebmer (2007) show that education is among the most important predictors for upward mobility: individuals holding an academic qualification experienced, on average, 6 percentiles greater relative growth compared to individuals with a lower level of education, even when controlling for a range of background, social, and employment attributes. Likewise, Bachmann et al. (2016) and Aristei and Perugini (2015) analyze patterns of earnings mobility across European countries and find that individuals with lower education levels have a reduced probability of upward earnings mobility.

Education is just one aspect of human capital that may generate differences in earnings mobility and there may be different mechanisms through which education influences individual earnings. Formal credentials may produce "signaling" (Spence 1974) and "sheepskin" effects (Hungerford and Solon 1987) that provide access to labour market positions—and potentially earnings mobility over time—through status attainment rather than through the cognitive skill gains education can provide. Because of this, education credentials are a proxy for human capital and often reflective of learning earlier in the life course and sociodemographic factors, such as family background (Manzoni et al. 2014; Sakamoto et al. 2018). More direct measures of skill generate additional insight into how human capital promotes social and economic well-being in adulthood (Heckman and Corbin 2016), which we discuss next, and are often more comparable measures across country contexts with different education systems (Hanushek and Woessmann 2008). Thus, the present study contributes to existing research on human capital and earnings mobility by considering the contribution of cognitive skill level as a more direct but rarely measured aspect of human capital that may have a distinct association with earnings mobility.

3 Extending human capital theory: distinguishing between acquired and utilized skills

Multiple bidirectional pathways characterize the relationship between cognitive skill level and education, both of which also relate to personal resources and opportunities within social contexts. On the one hand, an individual's skill level in adulthood is influenced by their educational background (OECD 2013a). On the other hand, early ability simultaneously contributes to that very level of educational attainment (Ou and Reynolds 2014). Although average skill levels generally rise with higher education levels and years of schooling (OECD 2013a), they also vary in reference to other experiences, such as employment and training history (Hampf and

Woessmann 2017). Education level remains constant for adults who do not return to school; yet, there is evidence that skill levels do continue to change over the life course after finishing education (Cunha et al. 2006; Desjardins and Warnke 2012). Therefore, education and cognitive skill level represent related and complementary aspects of human capital that may have distinct associations with earnings mobility.

Cognitive skill level also relates to the extent to which an individual engages in skill-based activities (OECD 2013a). "Possessing" human capital through individual education and skill level may have a different relationship with earnings mobility compared to "using" or "applying" this capital. Re-framing human capital as connected to everyday practices and the opportunity to employ capabilities is an extension made to neo-classical human capital theory (Klees 2016). Job-requirement analysis emphasizes the role of everyday activities on both cognitive skill level and earnings. Activities that are non-routine and require information-processing skills are associated with higher earnings (Green 2012; Ederer et al. 2015; Mane and Miravet 2016; Mainert et al. 2018). Greater earnings for people who perform high-skill activities at work may be due to skill-biased technological change that decreases earnings for workers performing routine tasks (Autor et al. 2003; Spitz-Oener 2006; Goos and Manning 2007). Few studies, however, consider the association between earnings mobility and the opportunity for skill use and skill-demands of employment. Some evidence comes from Coban (2017) who analyzes the relationship between workplace activities and earnings mobility in Germany between 1984 and 2014, and demonstrates that people who perform mainly manual tasks have lower mobility compared to those who perform primarily non-manual tasks.

Although prior research demonstrates that earnings differentials relate to education (e.g., Connolly and Gottschalk 2006) and cognitive skills (e.g., Hanushek et al. 2015), as well as skill-based activities at work (e.g., Liu and Grusky 2013), the majority of this research relies on cross-sectional data and does not generate insight into how all three aspects relate to earnings mobility. While it is unknown if all three aspects of human capital facilitate access to higher earnings through mobility, prior research indicates that the earnings returns to cognitive skills increase with age (Lin et al. 2018) or time spend in a job, for example, when employers learn more about the skills of their workers (Altonji and Pierret 2001). Education level is also associated with career progression, often through occupational sorting (Manzoni et al. 2014) and job mobility (Becker and Blossfeld 2017). Therefore, the present study takes a complementary dynamic perspective that considers how earnings change over time among

Table 1 Canada and Germany country profiles

	Canada	Germany	OECD
Job protection, union density, temporary employment			
Job protection against individual dismissal, permanent workers, 2013[a]	0.92	2.53	2.03
Specific requirements for collective dismissal, 2013[a]	2.97	3.63	2.89
Regulation on temporary forms of employment, 2013[a]	0.21	1.75	2.07
Share of temporary employment (age 25–54), 2017[b]	10.3	9.6	10.2
Trade union density, 2015[c]	29.4	17.6	26.3
Collective bargaining coverage, 2015[d]	28.4	56.8	32.7
Job tenure (% age 25–54), 2015[e]			
< 12 months	15.1	12.4	15.5
1–3 years	18.9	13.6	13.2
3–5 years	13.8	12.9	12.7
5–10 years	22.4	20.5	24.2
10 years +	29.9	40.6	31.6
Income inequality			
GINI index of disposable income (post tax/trans., age 18–65), 2015[f]	0.322	0.301	0.315
Mismatch, 2016[g]			
Under-qualification	21.7	19.7	18.9
Over-qualification	16.2	17.2	16.8
Public expenditure on labour market programs, 2016[h]			
Total (as a percentage of GDP)	0.90	1.45	1.25
Total active measures	0.25	0.63	0.52
Training-related active measures	0.07	0.19	0.12
Passive measures	0.65	0.82	0.74

[a] Source: The OECD indicators on Employment Protection Legislation. Scale from 0 (least restrictive) to 6 (most restrictive)

[b] Source: OECD.stat, Employment by Permanency (Dataset: Labour Force Statistics)

[c] Source: OECD.stat, Trade Union (Dataset: Trade Unions and Collective Bargaining)

[d] Source: OECD.stat, Collective Bargaining Coverage (Dataset: Trade Unions and Collective Bargaining)

[e] Source: OECD.stat, Employment by job tenure intervals (Dataset: Labour Force Statistics)

[f] Source: OECD.stat Income Distribution Database (Dataset: Social Protection and Well-being)

[g] Source: OECD.stat Mismatch (Dataset: Labour)

[h] Source: OECD.stat Public expenditure and participant stocks on LMP (Dataset: Labour)

the same individuals in Canada and Germany. Comparing these two contexts offers a way to understand if there is variation in the role of both acquired (i.e., cognitive skills and credentials) and utilized (i.e., skill-based activities) human capital for earnings mobility and how it differs by context.

4 The German and Canadian contexts

The association between human capital and earnings is known to vary by context. International comparative research based on cross-sectional data shows that although cognitive skill level typically has a positive association on individual earnings both before and after accounting for education level (e.g., Hanushek et al. 2015), the association is often weaker in continental European countries compared to the United States, Canada, and the United Kingdom (Leuven et al. 2004; Blau and Kahn 2005). In addition, there is cross-sectional

evidence that the association between cognitive skills and earnings is stronger in countries that have a greater dispersion in earnings (Jovicic 2016), while higher levels overall are associated with a more equal distribution (Afonso et al. 2010). Institutional and policy differences may also matter, such as the level of unionization, the strength of employment-protection legislation, the size of the public sector, and the amount of the minimum wage (Hanushek et al. 2015; Broecke et al. 2017).

Our research draws upon two contexts that are often typified as examples of liberal and coordinated market economies (Hall and Soskice 2001). In liberal market economies like Canada, competitive market arrangements generate more flexible forms of employment compared to coordinated market economies like Germany where job protection is more stringent. As Table 1 indicates, Canada has comparably low levels of job protection, regulation on temporary employment, and length of

job tenure compared to Germany and the OECD average; however, Germany and Canada have a similar share of temporary employees overall. Although Canada appears to deviate from a typical deregulated labour market in terms of its high level of trade union density, collective bargaining coverage across all employees is lower than the OECD average and in Germany.

Certain types of skills are also promoted within each context, especially in relation to differences in education systems, employment-based training, and vocational education (Estevez-Abe et al. 2001). Germany is often cited as an example of a context that places high importance on standardized formal qualifications (Allmendinger and Hinz 1997). It promotes high levels of vocational training to streamline the transition between school and work and reduces education-employment mismatch (Hofacker and Blossfeld 2011). This also means that individuals are often closely tied to their occupational field and experience fewer career changes. While Canada also offers vocational education and training, a comparably smaller proportion of post-secondary students pursue this pathway and instead gain credentials in college and university programs that may offer some (but typically more limited) opportunities for on-the-job training, especially in fields that do not lead to specific forms of accreditation (Kirby 2007). As illustrated in Table 1, although Germany has a higher level of public expenditure on overall and training-based labour market programs compared to Canada, the proportion of people in Canada and Germany considered as under- or over-qualified is similar.[1]

Prior research on earnings mobility in Canada and Germany highlights country similarities and differences. In terms of similarities, Chen (2009) shows that in the 1990s and early 2000s Canada and Germany had similar and high rates of two-year earnings stability (i.e., approximately 45–50% of the sample remained in the same earnings decile) and a lower rate of mobility compared to other countries in the study. Yet, the similarity in stability could be due to different reasons. Analyzing the role of institutions on earnings mobility, Pavlopoulos (2007) and Pavlopoulos et al. (2010) argue that both unionization (as in Canada) and employment protection (as in Germany) may support greater stability and less downward and upward mobility. Both forms of employment protection mean employers face barriers to firing workers that results in fewer job changes and thus lowers mobility (Bachmann et al. 2016). Still, Chen (2009) demonstrates that half of all workers do experience short-term upward or downward mobility in both contexts.

High rates of temporary employment in both Canada and Germany may be a contributing factor as job change typically results in more volatile earnings over time (Aristei and Perugini 2015).

Along with context differences, it is also important to consider if cognitive skills, education, and the skill use/demands at work have different relationships with earnings in Canada and Germany. Both countries have similar associations between cognitive skill level and cross-sectional earnings; for example, in a baseline model, Hanushek et al. (2015) find that, for each standard deviation increase in numeracy skills, earnings increase by 19.3% in Canada and 23.5% in Germany.[2] In addition, the earnings returns to literacy skills are largely the same across groups with different educational credentials in both countries (OECD 2013a). To the best of our knowledge, there is no research on the relationship between skill-based activities and earnings that compare results for Canada and Germany. Although Pouliakas and Russo (2015) use data from both countries and find a positive association between various job tasks (e.g., abstract reasoning) and earnings using cross-sectional data, they only report pooled results and there are no conclusions about the potential country differences.

5 Analytical approach
5.1 Data and sub-samples
Data for our analyses come from the Canadian and German samples of the PIAAC study. Initiated by the OECD, PIAAC aims to provide internationally comparable measures of skills among adults age 16 to 65 through a computer-assisted in-person survey that focuses on sociodemographic characteristics, employment, skill use at home and work, and assessments of cognitive skills in three domains: literacy, numeracy, and problem-solving in technology-rich environments. Both Canada and Germany first participated in late 2011 and early 2012 and extended their PIAAC studies longitudinally, providing a unique opportunity to examine how cognitive skill level is related to short-term outcomes between 2012 and 2016.

The Canadian longitudinal data comes from the Longitudinal and International Study of Adults (LISA) survey that includes a sub-sample of PIAAC participants ($n = 8598$ in 2012) who answered the complete PIAAC background questionnaire and undertook the cognitive skill assessments. Due to attrition, the overall sample size of LISA-PIAAC respondents changed between 2012 and 2016 and, by 2016, there were only 4796 respondents. The German longitudinal data comes from the

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[1] Different measures of mismatch may suggest different findings; for example, Pellizzari and Fichen (2017) suggest Germany has a higher proportion of over- and under-qualified workers compared to Canada.

[2] Of note, these rates decrease to 12.9% for Canada and 14.8% for Germany once a model accounts for years of schooling.

PIAAC-Longitudinal (PIAAC-L) study that followed up with PIAAC respondents over three additional waves. Like Canada, there is attrition over time and the German sample diminished from 5465 in 2012 to 2967 in 2016. In all analyses, we apply longitudinal sampling weights that correct for attrition in both countries.[3]

Our analyses use survey responses and assessment data from Canadian LISA-PIAAC and German PIAAC-L respondents who participated in the 2012 and 2016 surveys. Among these respondents, all analyses exclude individuals who were unemployed, self-employed, or in school ($n=2150$ in Canada, $n=1410$ in Germany) and did not report earnings ($n=626$ in Canada, $n=174$ in Germany) in 2012 and 2016. To reduce the influence of outliers and atypical earnings, the top and bottom 1% of the earnings distribution in 2012 and 2016 are also excluded ($n=61$ in Germany, $n=65$ in Canada). Finally, there is a small amount of missing information at the covariate level ($n=17$ for Canada, $n=2$ for Germany) to which we apply listwise deletion.[4] With these exclusions, our final sample sizes are 1,320 individuals in Germany and 1,938 individuals in Canada.

5.2 Variables

5.2.1 Dependent variables

Our main dependent variables are constructed from adjusted self-reported before-tax earnings (not including bonuses) in 2012 and 2016.[5] While the German PIAAC-L survey reports monthly earnings, the Canadian LISA survey reports weekly earnings that are multiplied by four to ease comparability.[6] As Fig. 1 illustrates, the earnings distribution is similar in 2012 across both contexts; however, in 2016, average earnings have changed to a much smaller degree in Canada compared to Germany.

The first part of our analysis comprises three inequality and mobility indices and uses the original continuous measure of adjusted monthly earnings. In addition, we transform earnings information into deciles to capture an individual's relative position in the distribution of earnings in 2012 and 2016 and the experience of upward, downward, or no positional change over the four-year period.[7] As we will discuss further below, the final part of the analysis transforms 2012 and 2016 earnings into a measure of positional change between the two periods.

#### 5.2.2 Independent variables

Our main independent variable of interest is numeracy skills, one of the three cross-nationally validated information processing skills measured in PIAAC 2012. This comprehensive assessment comprises of 56 items that test "the ability to access, use, interpret, and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life" (OECD 2013a, 59).[8] According to the updated Cattell-Horn-Carroll theory of intelligence (McGrew 2009; Schneider and McGrew 2018), quantitative/math ability (i.e., Gq) is a broad skill domain at Stratum II and typically has the highest factor loading on general mental ability (i.e., G). That is, it correlates very highly with markers of general cognitive ability.[9] It is for these reasons that we consider the PIAAC numeracy measure as a proxy of general cognitive ability.

Our analysis uses numeracy skills, measured through 10 plausible values, in two ways. In the descriptive index-based analyses, scores are transformed into three coarse categories representing assessed skill level, namely levels 0/1, 2/3, and 4/5, typical groupings that roughly measure low, average, and high scores (for more information on level thresholds, see OECD 2013b). In the regression-based analyses, numeracy scores are included as a continuous standardized measure that represents each standard deviation increase in assessed score. Models involving cognitive ability are run separately for each of the 10 plausible values and the results are aggregated

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[3] It is necessary to detail the weighting strategy given the complex survey design of PIAAC and survey design differences between Canada and Germany. First, all indices and models that measure skill level use the 10 plausible values produced for the PIAAC assessment scores (OECD 2013b). Second, all longitudinal indices and models include the longitudinal sampling weights produced separately for Canada and Germany to account for survey design and attrition. For the Canadian analysis, the corresponding 1,000 bootstrap weights are also used to estimate the sampling variance.

[4] In a very small number of cases, we were able to reconstruct missing values using responses to other survey waves: five German respondents did not report their firm size in 2012 but reported it in later waves without experiencing a job change; three German respondents did not report their work hours in 2016 but did so in 2015; and three Canadian respondents did not provide their highest education level in 2012 but did in 2014.

[5] To generate greater comparability between Canada and Germany and account for inflation, earnings are adjusted using purchasing power parities (PPP) information from the OECD (for more information, see: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm).

[6] Given the construction of the dependent variables is based on an individual's relative position in the earnings distribution, this small difference should not impact the comparison of results between the two countries.

[7] An alternative approach to measuring mobility—one that is based on an individual growth approach rather than a positional change approach—is to measure the change in earnings between time one and time two as the dependent variable. As reported in Appendix B, these models produce similar results to the positional change models in the main results section.

[8] PIAAC includes assessments for literacy, numeracy, and technology-solving in technology-rich environments skills. As there is a strong correlation between all three skill domains, ranging from 0.740 to 0.868 in Canada and 0.753 to 0.872 in Germany, we report results for numeracy skill only. Sensitivity analyses show the results for literacy to be very similar and are available in Appendix B.

[9] According to ongoing work (Engelhardt et al. n.d.), this correlation is $r = .70$ on the latent-variable level.
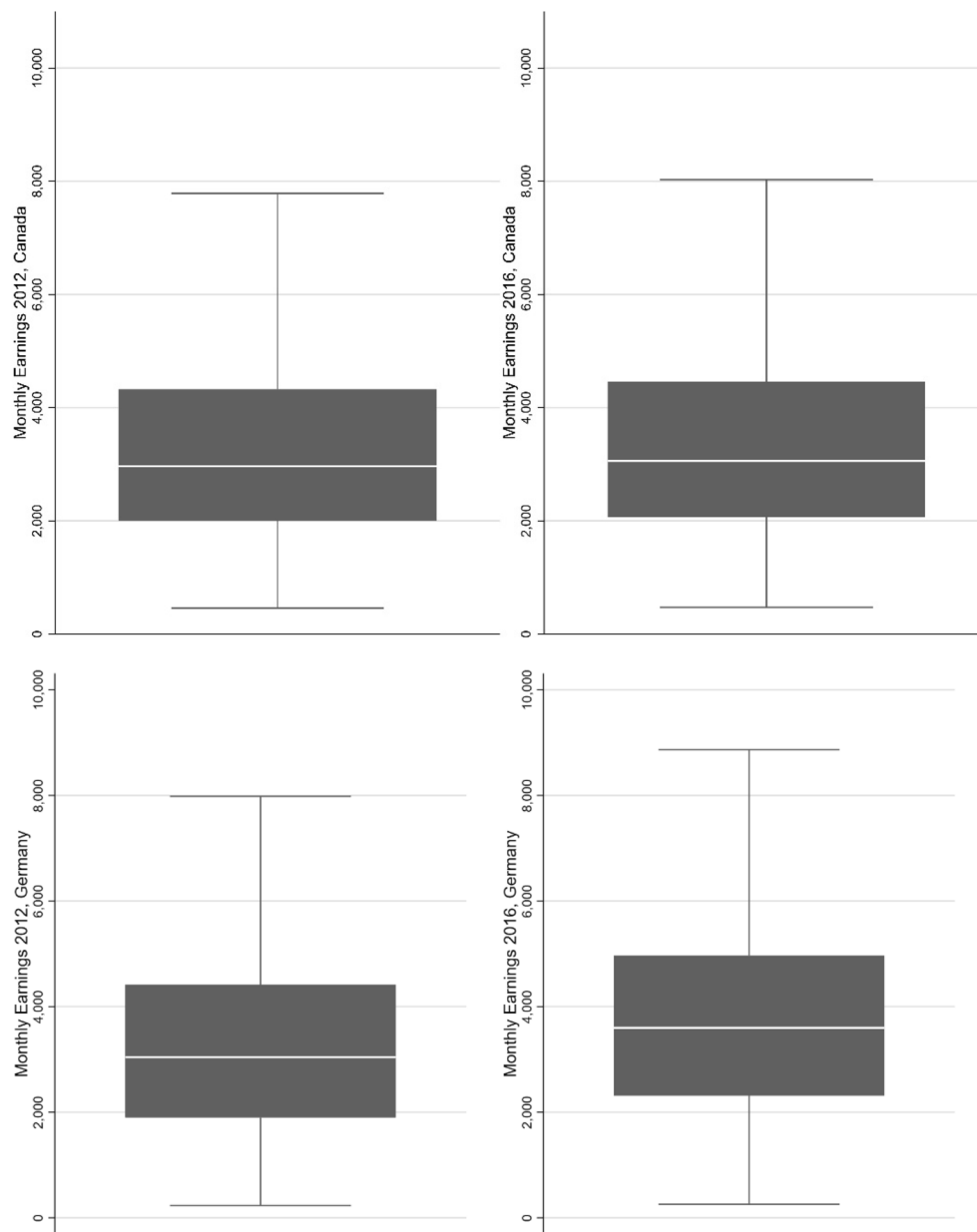
Fig. 1 Earnings Distribution in 2012 and 2016. Box-and-whiskers plots graphically portray the quartile distribution of adjusted monthly earnings in 2012 and 2016 for Canada and Germany. The top and bottom 1% of the earnings distribution are trimmed

with corrected standard errors (for further details on using plausible values, see Wu 2005).

The other key independent variables of interest are highest education level and skill use and demands at work. As measured in 2012, four education levels distinguish among respondents who have: (1) a high-school diploma or less (i.e., ISCED level 3 and under)[10]; (2) a

vocational education and training (VET) post-secondary education (PSE) below the bachelor's degree level but above the high-school level (i.e., ISCED levels 4 & 5 with a VET specialization)[11]; (3) a non-VET PSE (or first stage tertiary) credential below the bachelor's degree level (i.e., ISCED levels 4 & 5 without a VET specialization); and 4)

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[10] In Germany, this includes a large number of individuals with a credential below the high school level *and* a vocational qualification (i.e., "Berufsausbildung").

[11] In Germany, this category includes individuals with advanced (vocational) qualifications not obtained at universities (i.e., "Meister" and "Berufs- / Fachakademie").

a credential at the bachelor's (BA) degree level or above (ISCED level 5A/6 +).

Two dummy variables measure if participants reported engaging in advanced math and reading at work in 2012. To measure advanced math at work, we use two PIAAC background questionnaire items that ask how often participants use simple algebra, formulas, advanced math, or statistics at work and construct a dummy indicator that captures people who engage in any of these activities at least once a month. To measure advanced reading at work, respondents who report reading professional journals, publications, or books at least once a month are coded as using advanced reading skills. The analysis also includes a dummy measure of workplace discretion in 2012 constructed from a single question that asked respondents the extent to which they have flexibility in how they do their work and group people who answered to a "high" or "very high" extent as having discretion at work.

5.2.3 Control variables

In the regression analyses, several additional independent variables capture possible individual, employment, and geographical factors. We include dummy indicators measuring gender and native-speaker status (i.e., if a respondent is a native English/French or German speaker) and a categorical variable that captures three age groups in 2012 (age 34 or younger, 35–54, and 55 or older). As changing jobs or working hours will likely affect earnings mobility, a dummy variable measures if respondents changed jobs between 2012 and 2016 and a continuous variable measures the change in working hours between the same period. Further job characteristics that may influence the likelihood of receiving a raise comprise firm size, public/private sector, part-time employment status, and more than one job in 2012. Given possible regional effects, binary variables measuring area of residence in 2012 capture provinces in Canada and East/West Germany. A continuous measure captures potential years of labour market experience by 2012 (i.e., age minus six minus years of schooling). Two binary measures also capture if a respondent was living with a spouse or partner in 2012 and/or had a child under six years old in 2012. Appendix A provides summary statistics for all independent and control variables.

5.3 Analysis

As a descriptive overview of the nature of earnings mobility and its contribution to overall and group-based inequality in each country, descriptive analyses of earnings mobility examine three indices as well as decile transitions between 2012 and 2016. First, the Gini (1921) index I_{Gini} estimates the level of earnings inequality within each country. Separately in 2012 and 2016, it summarizes the

level of earnings inequality in the original continuous distribution of earnings by measuring the mean difference between all possible earnings in the sample, with higher values signaling greater levels of inequality. In Eq. (1), $y_i(y_j)$ represents the earnings of the individual and $\bar{y}$ represents the average earnings in the sample:

$$I_{Gini} = \frac{1}{2N^2\bar{y}} \sum_{i=1}^{N} \sum_{j=1}^{N} |y_i - y_j| \tag{1}$$

Second, to capture positional movement in the original continuous distribution of earnings, the Fields and Ok (1996, 1999) mobility index M_{FO} estimates the average overall level of change in monthly earnings between 2012 and 2016 (i.e., $earnings_{i2016}$ and $earnings_{i2012}$), with higher values signaling greater mobility overall:

$$M_{FO} = \frac{1}{N} \sum_{i=1}^{N} |earnings_{i2016} - earnings_{i2012}| \tag{2}$$

Third, the Fields (2010) index M_F is a measure of the extent to which mobility equalizes the distribution of earnings over time. A zero value indicates that mobility does not change inequality in the distribution of earnings between 2012 and 2016. A positive value indicates lower inequality through greater upward mobility among individuals located within the lower end of the earnings distribution. A negative value indicates higher inequality over time through greater upward mobility among individuals located within the higher end of the earnings distribution. The Fields index relies on the Gini index as a measure of inequality in 2012 (y_0) and a vector of earnings change between 2012 and 2016 ($\bar{y}$):

$$M_F = 1 - \frac{I_{Gini}(\bar{y})}{I_{Gini}(y_0)} \tag{3}$$

Fourth, descriptive statistics provide insight into earnings decile transitions; that is, the proportion of respondents in Canada and Germany who changed earnings decile between 2012 and 2016. Upward mobility is measured as belonging to a higher decile in 2016 compared to 2012, no change is measured as belonging to the same decile in 2012 and in 2016, and downward mobility is measured as belonging to a lower decile in 2016 compared to 2012. Given the distribution, the highest decile cannot experience upward mobility, while the lowest decile cannot experience downward mobility.

In the second part of our analysis, we perform multivariate analysis and use linear regression models to gauge the relative contributions of cognitive skills, skill use and demands at work, and education level to earnings mobility. Our dependent variable is a mobility measure that

Table 2 Earnings inequality and mobility indices for Canada and Germany

	Gini				Fields and Ok		Fields	
	Can		Ger		Can	Ger	Can	Ger
	2012	2016	2012	2016	12–16	12–16	12–16	12–16
Overall	0.288	0.287	0.323	0.313	0.296	0.261	0.061	0.056
Numeracy Skills in 2012: Level 0/1	0.290	0.276	0.290	0.328	0.396	0.353	0.117	0.054
Numeracy Skills in 2012: Level 2/3	0.270	0.276	0.308	0.293	0.292	0.261	0.052	0.062
Numeracy Skills in 2012: Level 4/5	0.237	0.232	0.284	0.257	0.252	0.236	0.073	0.080
Advanced math at work in 2012	0.245	0.251	0.285	0.273	0.271	0.227	0.047	0.053
No advanced math in 2012	0.291	0.286	0.323	0.314	0.316	0.307	0.071	0.066
Advanced reading at work in 2012	0.265	0.258	0.289	0.274	0.268	0.239	0.071	0.061
No advanced reading in 2012	0.276	0.289	0.333	0.327	0.334	0.305	0.047	0.065
Low discretion at work in 2012	0.297	0.288	0.316	0.313	0.302	0.309	0.070	0.056
High discretion at work in 2012	0.267	0.277	0.317	0.302	0.289	0.240	0.047	0.056
Education: HS or less	0.265	0.278	0.299	0.299	0.325	0.293	0.059	0.061
Education: VET PSE (below BA)	0.263	0.282	0.305	0.272	0.292	0.255	0.036	0.930
Education: non-VET PSE (below BA)	0.293	0.265	0.281	0.249	0.297	0.223	0.109	0.860
Education: BA degree or above	0.248	0.237	0.265	0.250	0.278	0.241	0.082	0.074

captures the change in earnings percentiles between 2012 and 2016. By definition, individual mobility can vary between 99 (i.e., indicating an increase from the bottom to the top of the distribution) and -99 (i.e., indicating a decrease from the top to the bottom of the distribution). For example, an individual who moved from the 50th percentile in 2012 to the 65th percentile in 2016 would have upward mobility of 15 percentiles. Models with this type of dependent variable are commonly termed relative change models (e.g., Raferzeder and Winter-Ebmer [2007]).

We use a series of models to examine how the relationship between mobility and skills changes when additional independent variables are added to the model. Model 1 only includes numeracy score and initial decile in 2012. Model 2 adds indicators measuring skill use and demands at work and Model 3 introduces the highest education level. As in the equation below, Models 4 adds a vector $\boldsymbol{\beta X}$ of control variables.

$$
\begin{aligned}
Mobility_i = & \beta_0 + \beta_1 Numeracy_i + \beta_2 Initaldecile_i \\
& + \beta_3 Mathatwork_i + \beta_4 Readingatwork_i \\
& + \beta_5 Discretionatwork_i + \beta_6 VETPSE_i \\
& + \beta_7 non-VETPSE_i + \beta_8 BAorabove_i \\
& + \boldsymbol{\beta X}_i + e_i
\end{aligned}
\tag{4}
$$

6 Results

6.1 Descriptive analyses of earnings mobility

Table 2 presents the results of the Gini, Fields and Ok, and Fields indices for the Canadian and German samples.

Overall, the Gini results are similar across both time periods but are slightly lower in Canada. In both contexts and periods, the Gini index decreases among individuals with the highest numeracy levels. In both Canada and Germany, people who self-report performing advanced math and reading at work have earnings that are more equal compared to those who did not. The Gini index is similar by level of workplace discretion in Canada and Germany in 2012 and 2016, although it is slightly higher in 2012 among respondents in Canada who report low workplace discretion relative to those who report high discretion. In both Canada and Germany, the Gini index is typically lowest among individuals with a BA degree or above in both 2012 and 2016; although in 2016, German respondents with a BA degree or above or non-VET PSE below the BA degree level have markedly similar results.

The Field and Ok index provides insight into the overall level of earnings mobility between 2012 and 2016, with higher values signaling greater mobility in terms of either upward or downward change. The overall index score is slightly higher in Canada, suggesting greater earnings mobility compared to Germany. In both countries, individuals with lower numeracy levels experience greater upward or downward mobility, as do people who self-report not performing advanced math or reading at work and being in positions with lower levels of discretion in 2012. Similar to the skill level results, respondents in Canada with higher credential levels typically experience lower mobility compared to people with lower education. In Germany, the Field and Ok index is similar across all

Table 3 Proportion of downward, same, and upward decile change, 2012 to 2016

	Canada			Germany		
	downward	*same*	*upward*	*downward*	*same*	*upward*
All	0.279	0.369	0.352	0.262	0.407	0.331
Numeracy Skills in 2012: Level 0/1	0.288	0.327	0.385	0.320	0.362	0.318
Numeracy Skills in 2012: Level 2/3	0.281	0.366	0.354	0.271	0.388	0.341
Numeracy Skills in 2012: Level 4/5	0.261	0.429	0.310	0.196	0.502	0.302
Advanced math at work in 2012	0.285	0.399	0.316	0.274	0.408	0.318
No advanced math in 2012	0.275	0.352	0.373	0.251	0.407	0.342
Advanced reading at work in 2012	0.287	0.356	0.373	0.268	0.406	0.326
No advanced reading in 2012	0.270	0.382	0.330	0.254	0.408	0.338
Low discretion at work in 2012	0.255	0.375	0.370	0.263	0.373	0.363
High discretion at work in 2012	0.309	0.363	0.328	0.261	0.426	0.313
Education: HS or less	0.304	0.354	0.342	0.295	0.376	0.329
Education: VET PSE (below BA)	0.328	0.412	0.260	0.238	0.438	0.324
Education: non-VET PSE (below BA)	0.253	0.353	0.393	0.227	0.442	0.330
Education: BA degree or above	0.238	0.371	0.390	0.216	0.445	0.339

three PSE education levels and lower when compared to those with a HS diploma or less.

For the Field index, positive and higher values signal that mobility has an equalizing effect on earnings inequality. The overall Field indices suggest earnings mobility equalizes earnings to a similar extent in Canada and Germany. However, mobility has a larger equalizing effect among individuals with the lowest numeracy levels in Canada and the highest numeracy levels in Germany. In Canada, the Field index is higher among individuals who do not use advanced math and self-report low levels of workplace discretion, but it is lower among those who do not have the opportunity to engage in advanced reading. In contrast, the Field index is similar by level of workplace discretion and reading activities in Germany, but higher for individuals who do not use advanced math at work. By education level, earnings equalize to a greater extent among individuals with a non-VET PSE credential in Canada and those with a VET PSE credential in Germany.

Table 3 assesses the proportion of individual upward or downward decile change and stability between 2012 and 2016. The overall results are comparable between Canada and Germany with only small differences. A slightly higher proportion of individuals in Germany are in the same earnings decile for both periods, while there are somewhat higher levels of upward and downward mobility in Canada. Consistent with the findings in Table 2, people with higher numeracy skill levels experience greater stability in Canada and Germany. Respondents who scored at skill levels 0 or 1 have the highest rate of

downward decile change in Germany, yet they also have slightly higher rates of upward change in Canada.

In both contexts, individuals who did not perform advanced math at work have somewhat higher rates of upward mobility, while those who did engage in advanced reading have higher rates of upward mobility in Canada. Individuals who have low levels of workplace discretion in both countries have higher rates of upward mobility. In Germany, people with high discretion at work have greater stability and lower rates of upward mobility compared to those with lower levels of discretion. In Canada, those with high discretion have higher rates of downward mobility and similar rates of stability compared to individuals with low discretion jobs. In both countries, individuals with a BA degree or above have the lowest rates of downward mobility. Although in Germany upward mobility is similar across all education levels, in Canada, individuals with a non-VET PSE credential and a BA degree or above have higher rates of upward mobility compared to the other two levels of education.

6.2 Multivariate analysis

Table 4 presents the results of relative change models that explain positional percentile change in monthly earnings between 2012 and 2016 for the Canadian sample. Model 1 demonstrates that, controlling for initial 2012 decile position, each standard deviation increase in numeracy scores relates to a 2.4 percentile upward change in the distribution of earnings over the four-year period. Although this coefficient may seem small at first glance, it is important to consider it in reference to the distribution of numeracy scores. For example, on average for the

Table 4 Relative change in Canadian monthly earnings percentiles, 2012 to 2016

	(1)	(2)	(3)	(4)
Numeracy	2.433** (0.759)	2.212** (0.760)	1.315 (0.777)	0.449 (0.706)
Initial position				
Earnings decile in 2012[a]	− 2.518*** (0.224)	− 2.696*** (0.255)	− 2.869*** (0.250)	− 2.999*** (0.333)
Work characteristics in 2012				
Advanced math at work[b]		1.102 (1.182)	0.999 (1.170)	0.832 (1.096)
Advanced reading at work[b]		2.549* (1.264)	1.515 (1.193)	2.151* (1.045)
High discretion[c]		− 0.113 (1.094)	0.149 (1.062)	0.696 (0.951)
Education				
VET PSE (below BA)[d]			1.249 (1.730)	1.625 (1.454)
Non-VET PSE (below BA)[d]			5.393*** (1.615)	4.588** (1.491)
BA degree or above[d]			7.329*** (1.509)	5.760*** (1.634)
Controls				
Female[e]				− 5.669*** (1.202)
Age: 34 and under[f]				− 0.400 (1.589)
Age: 55 and older[f]				− 1.576 (1.715)
Non-native language speaker[g]				0.079 (1.438)
No job changes between 12–16[h]				3.139** (1.214)
Change in working hours 12–16				0.600*** (0.068)
Firm size: 11–50 ppl[i]				4.421** (1.612)
Firm size: 51–250 ppl[i]				5.662*** (1.668)
Firm size: 251 + ppl[i]				6.705*** (1.769)
Public sector[j]				0.514 (1.036)
Part time status[k]				− 2.681 (1.602)
Labour market experience				− 0.247** (0.085)
More than one job in 2012[l]				− 0.011 (1.509)
Living with partner in 2012[m]				1.544 (1.127)
Child under 6 in 2012[n]				− 1.515 (1.282)
Region included				yes
Constant	14.728*** (1.330)	14.054*** (1.304)	11.877*** (1.476)	13.117** (4.035)
R^2	0.12	0.13	0.15	0.35
Observations	1938			

Standard errors in parentheses; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

[e] Reference group: men

[f] Reference group: aged 35–54 years

[g] Reference group: native speaker

[h] Reference group: job change between 2012 and 2016

[i] Reference group: firm size of 1–10 ppl

[j] Reference group: private sector

[k] Reference group: full-time employed

[l] Reference group: only one job in 2012

[m] Reference group: not living with partner in 2012

[n] Reference group: no child under 6 in household in 2012

entire original PIAAC sample, the difference between each skill level (e.g., level 1 versus level 2) is approximately one standard deviation. This means that in Model 1 individuals with skills at level four (i.e., high skills) are estimated to experience a relative change in earnings of roughly 9 percentiles compared to individuals who scored at level zero (i.e., low skills). Controlling for work characteristics reduces the numeracy coefficient slightly to 2.2 in Model 2. Education level has a large effect on the model and reduces the size and significance of the numeracy coefficient to 1.3 in Model 3. Finally, once Model 4 introduces all control variables, the numeracy coefficient reduces to a 0.4 percentile change.

In terms of the other independent variables of interest, advanced reading at work has an association with short-term positional change over four years and, in the final model (i.e., Column 4), results in an average increase of 2.2 percentiles between 2012 and 2016 among individuals who self-report engaging in these activities compared to people who did not. Although, the inclusion of education level in Model 3 reduces the size and the significance of the numeracy score coefficient, the final model results show that individuals with a non-VET PSE credential (below the BA level) have a 4.6 percentile change in earnings and those with a BA degree or above have a 5.8 percentile change in earnings between 2012 and 2016 compared to people with a high-school diploma or less. Importantly, the results demonstrate that education and skills do not have distinct correlations with positional earnings mobility in Canada when a regression model includes both variables.

Table 5 provides the results of the relative change model for Germany. In Model 1, each standard deviation increase in numeracy scores results in a 3.0 percentile increase in positional earnings between 2012 and 2016. Similar to Canada, the skill coefficient becomes smaller when controlling for work, education, occupational, and other individual characteristics. Nevertheless, the size of the association between skill and mobility for the German sample remains descriptively larger than the Canadian results across all models, and the coefficient remains statistically significant in Model 3 when controlling for education level.[12] Like the results for Canada, the final model indicates that education and skills do not have

distinct associations with earnings mobility over a four-year period in Germany once the model includes all control variables.

Regarding the other variables of interest, the results indicate that advanced reading skills at work has a positive relationship with earnings mobility across all models. Like Canada, performing advanced math at work does not have an association with later earnings mobility. Differing from the Canadian results, high discretion at work is only associated with greater mobility over time in the final model when controlling for all variables. Compared to individuals with a high school diploma or less, those with a non-VET PSE credential below the BA level are privy to a 3.4-point change in their earnings position and those with a BA degree or above have a 3.9-point change in their earnings position. Like Canada, there is no statistically significant difference in earnings position between individuals who have a VET PSE credential below the BA level compared to those with a high school diploma or less.

7 Discussion

As earnings stability and the possibility of upward mobility are key components of economic well-being, varying levels of mobility among only specific groups can imply growing inequality (Oh and Choi 2018; Tansel et al. 2019). Previous literature demonstrates that individuals with higher education levels are more likely to experience upward earnings mobility and stability over short and long periods of time (Heckman et al. 1998; Connolly and Gottschalk 2006; Raferzeder and Winter-Ebmer 2007; Rauscher and Elliott 2016). Nevertheless, the relationship between human capital and earnings mobility is less straightforward than commonly assumed when considering cognitive skills and skill use/demands at work alongside education level.

Contributing to research on the influence of human capital on earnings mobility, the present article examines how short-term earnings mobility over a four-year period differs by skill level in Canada and Germany. By taking into account skills, skill use and demands at work, and educational credentials, the aim is to identify how different measures of human capital interact and are associated with earnings mobility. Our research draws upon two contexts that are often typified as examples of liberal and coordinated market economies (Hall and Soskice 2001). In a liberal market economy such as Canada, competitive market arrangements should result in greater levels of mobility and a stronger association between general measures of human capital and positional change. In contrast, in coordinated market economies like Germany, where job protection is more stringent and high levels of employment-based training and vocational education

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[12] To investigate how economic development is related to earnings mobility, we also estimated the German results separately for West and East Germany. The results for the West German sample are broadly consistent with the results in Table 5. The main differences are that the coefficient for numeracy is slightly larger and also statistically significant in Model 4. For the East Germany sample, we find no statistically significant relationship between numeracy and earnings mobility, a result that is likely due to the small sample size ($n = 245$). Using a larger dataset, future studies should further investigate potential regional differences.

Table 5 Relative change in German monthly earnings percentiles, 2012 to 2016

	(1)	(2)	(3)	(4)
Numeracy	3.011*** (0.630)	2.715*** (0.635)	2.157** (0.675)	0.804 (0.539)
Initial position				
Earnings decile in 2012[a]	− 1.924*** (0.190)	− 2.145*** (0.232)	− 2.330*** (0.240)	− 2.756*** (0.289)
Work characteristics in 2012				
Advanced math at work[b]		0.861 (1.096)	0.829 (1.086)	1.154 (0.906)
Advanced reading at work[b]		3.137** (1.011)	2.337* (1.015)	3.034*** (0.873)
High discretion[c]		0.794 (0.907)	0.750 (0.912)	1.629* (0.817)
Education				
VET PSE (below BA)[d]			0.367 (1.731)	0.305 (1.390)
Non-VET PSE (below BA)[d]			3.318* (1.471)	3.431* (1.404)
BA degree or above[d]			4.761** (1.493)	3.910* (1.545)
Controls				
Female[e]				− 4.240*** (0.865)
Age: 34 and under[f]				− 1.554 (1.565)
Age: 55 and older[f]				0.886 (1.816)
Non-native language speaker[g]				− 2.688 (1.808)
No job changes between 12–16[h]				2.911* (1.257)
Change in working hours 12–16				0.760*** (0.066)
Firm size: 11–50 ppl[i]				2.348 (1.243)
Firm size: 51–250 ppl[i]				4.022** (1.257)
Firm size: 251 + ppl[i]				5.592*** (1.443)
Public sector[j]				1.882* (0.903)
Part time status[k]				− 2.986* (1.380)
Labour market experience				− 0.305*** (0.077)
More than one job[l]				− 0.805 (1.533)
Living with partner in 2012[m]				− 2.022* (0.946)
Child under 6 in 2012[n]				− 0.193 (1.286)
Region included				yes
Constant	11.516*** (1.131)	9.962*** (1.187)	9.836*** (1.220)	17.014*** (3.426)
R^2	0.11	0.12	0.13	0.42
Observations	1320			

Notes: Standard errors in parentheses; $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

[e] Reference group: men

[f] Reference group: aged 35–54 years

[g] Reference group: native speaker

[h] Reference group: job change between 2012 and 2016

[i] Reference group: firm size of 1–10 ppl

[j] Reference group: private sector

[k] Reference group: full-time employed

[l] Reference group: only one job in 2012

[m] Reference group: not living with partner in 2012

[n] Reference group: no child under 6 in household in 2012

emphasize industry-specific over general forms of human capital (Estevez-Abe et al. 2001), we expect to find lower mobility and a weaker association between general skills and mobility. However, our results demonstrate similarities and differences in both countries, as well as patterns that deviate from the liberal and coordinated market typology.

In terms of similarities between Canada and Germany, the level of overall earnings inequality (as measured by the Gini index) is slightly lower for individuals with higher skill levels and educational credentials in both countries. The Field and Ok index indicates that individuals in Canada and Germany with higher skill levels experienced greater earnings stability between 2012 and 2016, as did those who self-reported performing advanced reading and numeracy workplace activities and holding a PSE credential. In the baseline multivariate models, there is a positive relationship between skills and upward mobility for respondents in both Canada and Germany. Advanced reading at work and holding a non-VET PSE credential below the BA level or a BA degree or above are also associated with short-term upward percentile mobility, controlling for all other factors, in both Canada and Germany.

Despite the overall cross-country similarities, the findings are not universal and there are some notable differences between the Canadian and German results. Over the four years under consideration, the Field index results suggest that earnings became more equal for individuals with a non-VET PSE credential below the BA level and those with lower numeracy levels in Canada, while in Germany earnings became more equal among individuals with VET PSE credential below the BA level and higher numeracy levels. The relative change model also demonstrates that both numeracy skill and education levels have distinct associations with upward mobility in Germany prior to controlling for other variables in Model 3, while the numeracy coefficient becomes non-significant once the same Canadian model specification includes education level. However, once Model 4 includes all control variables, there is no distinct association between skills and positional change in Germany. Finally, the relative change models also illustrate that workplace discretion is associated with positive mobility in Germany but not Canada.

Our findings offer important insight into the relationship between multiple measures of human capital and earnings mobility. In part, the different measures connect to prior research that differentiates among what Estevez-Abe et al. (2001) term firm-specific skills (e.g., workplace tasks), industry-specific skills (e.g., VET education), and general skills (e.g., direct measures of cognitive skills). This and other typologies tend to focus on the specificity

and portability of skills and how they impact the economic behaviour of individuals in different contexts. This study goes beyond this research and aims to provide a clearer understanding of how different measures of human capital—that is, education and cognitive skills, as well as the opportunity for skill use and the skill-demands of employment—are associated with earnings mobility. In this way, it also adds to the argumentation that there is a need to re-situate research on the economic returns to human capital that is not based on individual skills alone, but on a combination of credentials, skills, and workplace opportunities that generate socioeconomic inequality even over short periods of time (see e.g., Kleese 2016).

Our research has implications for understanding the relationship between human capital and earnings mobility. In line with theories of "signaling" and "sheepskin" effects, it confirms that people with higher education levels—especially non-VET PSE credentials in both Canada and Germany—are privy to greater levels of earnings mobility compared to those with lower levels of education even when controlling for observed ability. Policy that supports skill development often aims to improve economic well-being, with "the belief that better-educated citizens yield a wealthier country [...] a cornerstone of public policy almost everywhere" (Hunter and Leiper 1993, 22). Underlying these policies is belief in meritocracy that assumes people with higher education levels have greater earnings due to their greater abilities. However, the results suggest that even among people with the same ability (at least measured in terms of cognitive skills), those with a non-VET PSE credential experienced greater mobility overall. Thus, it is not necessarily skill but also formal credentials that relate to earnings mobility over time.

8 Conclusion

Although we provide several new insights into the relationship between measures of human capital and earnings mobility, there are limitations that are necessary to discuss. Although the majority of our indicators were measured prior to earnings mobility between 2012 and 2016, we do not establish causal mechanisms in this study as there may be unobserved confounders that generate spurious relationships and reverse causation is still possible. As the literature review discusses, cognitive skills and education have a reciprocal relationship; that is, education credentials are strongly associated with cognitive skills that, in turn, often increase at higher levels of education. Thus, it is likely that the reduction in the cognitive skill coefficient once a model controls for education level (i.e., Models 3 and 4) is partially explained by variance in education that is associated with cognitive skills earlier in the life course. Even

if the observed associations are causal, it is beyond the scope of our study to fully unravel the mechanisms through which cognitive skills, education level, or other measures of human capital affect earnings mobility.

A second limitation is that the analysis only contrasts similarities and differences between the Canadian and German results and does not formally test differences between contexts or sub-populations. We could formally test governmental, policy, or educational differences cross-nationally through multi-level modeling if all countries participating in PIAAC (i.e., over 40 as of 2020) included longitudinal earnings data. Because of the final sample size, the study does not assess how the findings differ by other sociodemographic characteristics. Prior research demonstrates that returns to human capital differ by gender and race (e.g., Hu et al. 2019) and thus future research must assess how the association between mobility and human capital differs among social groups.

Even with these limitations, our contribution has key strengths. It uses unique longitudinal data with direct assessment tests that allow for an expansion of commonly used measures of human capital and furthers research on "the extent to which modern, knowledge-based labor markets reward skills" (Hanushek et al. 2015, 123). The study provides insight into how both acquired and utilized human capital are associated with earnings mobility, evidence that generates avenues for future research and theoretical development. In particular, it is necessary to expand signaling theories that typically surround employer recognition of credentials during the hiring process and consider the mechanisms behind why these same credentials are associated with earnings mobility, even when controlling for individual cognitive skills. While prior research indicates that perceived skills are related to work promotion and retention (Furnham and Petrides 2006), it will also be necessary for future research to deepen insight into why cognitive skills and education level do and do not have separate associations with earnings mobility in certain contexts. Our comparative case study approach allows for the beginning of theory development as it assesses the extent to which the findings are context dependent.

Appendix A: Summary Statistics for Independent Variables
See: Table 6.

Table 6 Summary statistics

	Canada (%)	Germany (%)
Numeracy: Level 0/1	12.38	9.88
Numeracy: Level 2/3	72.14	70.85
Numeracy: Level 4/5	15.48	19.27
Advanced math at work[a]	36.53	46.59
Advanced reading at work[a]	49.90	58.20
High discretion[b]	43.62	64.58
Education: High school diploma or less	30.47	53.37
Education: VET PSE (below the BA level)	18.61	8.76
Education: non-VET PSE (below the BA level)	21.98	15.85
Education: BA degree or above	28.94	22.01
Female	48.09	47.74
Age: < 35 years	31.28	21.57
Age: 35–54 years	56.99	66.71
Age: > 55 years	11.73	11.72
Non-native language speaker[c]	18.28	7.83
No job change between 12–16[d]	68.53	77.84
Change working hours 12–16 (mean and SD)	1.73 (11.46)	0.57 (9.65)
Firm size: < 10 ppl	17.7	22.49
Firm size: 11–50 ppl	31.15	26.38
Firm size: 51–250 ppl	26.53	25.09
Firm size: > 251 ppl	24.62	26.05
Public sector employee[e]	28.72	23.26
Part-time employee[f]	9.53	20.49
Labour market experience (mean and SD)	20.48 (11.62)	22.61 (10.05)
More than one job in 2012[g]	9.38	8.80
Living with partner in 2012[h]	68.18	75.92
Child under 6 in 2012[i]	14.49	9.79
Observations	1938	1320

Table shows percentages unless stated otherwise. Survey weights provided by the OECD are used

[a] Reference group: little math/reading at work

[b] Reference group: low discretion

[c] Reference group: Native speaker

[d] Reference group: job change between 2012 and 2016

[e] Reference group: private sector

[f] Reference group: full-time employee

[g] Reference group: only one job in 2012

[h] Reference group: not living with partner in 2012

[i] Reference group: no child under 6 in household in 2012

Appendix B: Sensitivity Tests
Relative change models with literacy instead of numeracy
See Tables 7 and 8.

Table 7 Relative change in Canadian monthly earnings percentiles, 2012 to 2016

	(1)	(2)	(3)	(4)
Literacy	2.327** (0.710)	2.092** (0.703)	1.076 (0.738)	0.389 (0.683)
Initial position				
Earnings decile in 2012[a]	− 2.450*** (0.214)	− 2.636*** (0.249)	− 2.822*** (0.244)	− 2.990*** (0.332)
Work characteristics in 2012				
Advanced math at work[b]		1.352 (1.170)	1.216 (1.155)	0.891 (1.084)
Advanced reading at work[b]		2.430 (1.265)	1.463 (1.195)	2.138* (1.043)
High discretion[c]		− 0.183 (1.097)	0.123 (1.062)	0.677 (0.947)
Education				
VET PSE (below the BA level)[d]			1.433 (1.714)	1.678 (1.450)
non-VET PSE (below the BA level)[d]			5.423*** (1.593)	4.619** (1.469)
BA degree or above[d]			7.413*** (1.517)	5.800*** (1.628)
Controls				
Constant	14.380*** (1.288)	13.750*** (1.259)	11.525*** (1.409)	13.039** (4.039)
R^2	0.12	0.13	0.15	0.35
Observations	1938			

Standard errors in parentheses; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

Table 8 Relative change in German monthly earnings percentiles, 2012 to 2016

	(1)	(2)	(3)	(4)
Literacy	2.566*** (0.574)	2.185*** (0.575)	1.585** (0.594)	0.710 (0.556)
Initial position				
Earnings decile in 2012[a]	− 1.802*** (0.177)	− 2.028*** (0.221)	− 2.246*** (0.234)	− 2.749*** (0.286)
Work characteristics in 2012				
Advanced math at work[b]		1.146 (1.115)	1.080 (1.103)	1.201 (0.927)
Advanced reading at work[b]		2.972** (1.013)	2.172* (1.014)	2.973** (0.874)
High discretion[c]		0.784 (0.904)	0.735 (0.913)	1.634* (0.814)
Education				
VET PSE (below the BA level)[d]			0.769 (1.733)	0.386 (1.405)
non-VET PSE (below the BA level)[d]			3.673* (1.453)	3.518* (1.386)
BA degree or above[d]			5.190*** (1.424)	4.026** (1.516)
Controls				x
Constant	10.848*** (1.059)	9.282*** (1.113)	9.166*** (1.132)	17.033*** (3.404)
R^2	0.10	0.11	0.12	0.42
Observations	1320			

Standard errors in parentheses; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

Change in earnings models
See Tables 9 and 10.

Table 9 Change in monthly earnings between 2012 and 2016, Canada

	(1)	(2)	(3)	(4)
Numeracy	164.758** (51.020)	149.534** (51.434)	98.261 (52.779)	41.315 (49.442)
Initial position				
Earnings decile in 2012[a]	− 70.573*** (16.492)	− 79.903*** (18.362)	− 90.075*** (18.148)	− 99.402*** (24.029)
Work characteristics in 2012				
Advanced math at work[b]		94.751 (85.715)	88.394 (86.093)	64.600 (83.474)
Advanced reading at work[b]		85.719 (84.010)	26.555 (81.798)	76.947 (72.825)
High discretion[c]		28.380 (75.708)	43.490 (74.343)	73.583 (67.010)
Education				
VET PSE (below the BA level)[d]			48.073 (127.489)	78.202 (108.759)
non-VET PSE (below the BA level)[d]				
BA degree or above[d]			291.085** (96.151)	261.523** (94.451)
Controls				x
Constant	962.432*** (86.513)	922.661*** (85.960)	806.987*** (94.109)	1074.640*** (278.466)
R²	0.02	0.03	0.04	0.25
Observations	1938			

Standard errors in parentheses; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

Table 10 Change in monthly earnings between 2012 and 2016, Germany

	(1)	(2)	(3)	(4)
Numeracy	197.478*** (41.221)	176.658*** (41.615)	146.669** (43.404)	47.131 (37.782)
Initial position				
Earnings decile in 2012 [a]	− 61.965*** (14.195)	− 75.886*** (16.987)	− 87.310*** (17.531)	− 109.993*** (20.906)
Work characteristics in 2012				
Advanced math at work [b]	75.909 (80.579)	73.791 (79.672)	83.195 (66.183)	75.909 (80.579)
Advanced reading at work [b]	192.579** (65.110)	145.322* (64.650)	179.622*** (52.426)	192.579** (65.110)
High discretion [c]	24.618 (68.058)	25.302 (67.616)	81.918 (60.467)	24.618 (68.058)
Education				
VET PSE (below the BA level) [d]			− 29.953 (107.275)	− 44.950 (80.515)
non-VET PSE (below the BA level) [d]			132.630 (91.108)	129.414 (92.891)
BA degree or above [d]			298.565* (113.807)	231.408 (117.010)
Controls				x
Constant	824.187*** (76.815)	735.299*** (75.775)	739.553*** (76.598)	1115.776*** (246.033)
R²	0.04	0.04	0.05	0.33
Observations	1320			

Standard errors in parentheses; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] 2012 earnings decile as a continuous variable

[b] Reference group: little math/reading at work

[c] Reference group: low discretion

[d] Reference group: high-school diploma or less

Declarations

Ethics approval and consent to participate
All respondents gave informed consent prior to participation in the PIAAC study and its longitudinal components in Canada and Germany. As the following article is based on secondary data analysis, additional ethics approval is not necessary within the jurisdiction of this research.

Consent for publication
The authors consent to publication and are not aware of any reason why the following study cannot be published.

Competing interests
The authors declare that they have no conflict of interest.

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