Post-School Skill Production: New Measures and Patterns from the Canadian Longitudinal International Study of Adults (LISA)

July 22, 2024

Abstract

This paper uses innovative measures to study the production of skills in the post schooling period. Relatively informal forms of skill acquisition play a major role indicating more formal training only captures a small fraction of total on-the-job training. New evidence on the determinants of offer and take-up rates for training show most workers are offered and take-up training with variation in hours of training. Using a self-reported skill growth measure, we find that workers taking employer provided training often report no change in skill suggesting that some training is unproductive, or of too short a duration. Training hours for this group are less than 2 weeks over a 2-year period whereas training for large skill increases, by contrast, is often 1-2 months or more. Finally, more hours of training are strongly associated with higher skill production for workers who report employer provided training as being important for skill growth.

1 Introduction

The productivity of workers in the Canadian labour market is a topic of concern for policy makers. Increasing the average level of skill or human capital of workers is an important component of policy that aims to increase productivity. Immigration policy has been directed at recruiting highly skilled workers. Education policy aims, among other things, to equip students with range of skills, some of which are be immediately useful in the labour market on entry, and others which allow workers to produce labour market skills throughout the course of their labour market career. There is a large literature on how human capital is produced during early childhood and throughout the schooling period providing a basic understanding of the production of human capital in this phase of the life-cycle.[1] There is also a substantial, though smaller, literature on firm training but, in general, the production of human capital in the post school period is less well understood. In large part this is due to a lack of the kind of direct measures of inputs and outputs in the post schooling period that are available for the schooling period.[2] The Canadian Longitudinal International Study of Adults (LISA) provides a combination of innovative measures related to the production of skills in the post schooling period in a large panel. In this paper we use these measures to provide a more detailed picture of human capital production after labour market entry that goes beyond standard human capital empirical specifications.

The outline of the paper is as follows. Section 2 outlines the basic framework for human capital production after labour market entry used in the paper. In Section 3, the construction of direct measures of inputs and outputs for the post schooling period based on innovative skill related questions in LISA is described and their patterns are interpreted within this framework. Section 4 analyzes the relationship between input and output measures to provide evidence on the productivity of a variety of input types. Section 5 concludes with some suggestions for future work on post schooling production of skills based on the LISA panel.

[1] See the various volumes of the Handbook on the Economics of Education for a number of survey chapters. For other recent examples see, Cunha, Heckman and Shennach (2010) on production of cognitive and non-cognitive skills; Fu and Mehta (2018) on ability tracking, school and parental effort, and student achievement; and Mehta, Stinebrickner and Stinebrickner (2019) on time use and academic peer effects in college.

[2] In a comprehensive recent survey of firm training, Black, Skipper and Smith (2023) argue that: "Difficulties of measurement bear some of the blame for the lethargic pace of research on training over the past three decades"(p 4.).

2 Post-schooling Human Capital Production

The basic framework for studying human capital production in the post schooling period used in this paper is based on the standard Ben Porath approach. This framework has both stocks of human capital at a point in time and flows that either increase (human capital production) or decrease (depreciation) the stocks over time. Production takes place initially during a period of specialization in investment in human capital production - the schooling period - followed by a period where time is divided between earning and investing - the post schooling period. This basic framework of optimal investment in a single type of general human capital over the life-cycle used in Ben Porath (1967) was extended to multiple types of general human capital identified by education level, in part as a response to an observed increase in the college wage premium.[3] This framework retains a reasonable level of parsimony in that there are relatively few "types" of human capital, with their associated prices, and optimal life-cycle human capital investment profiles that can be derived for each type.

The predicted life-cycle profile from models of optimal human capital investment after the schooling period are most often captured empirically (descriptively) in Mincerian log wage equations that deal with wage levels and differenced log wage equations that capture wage growth. There are no systematic direct measures of the outputs or the inputs of time and other resources used in production of human capital over the labour market career analogous to test scores or grades and time spent studying in school for students in the schooling period.[4] In the absence of direct measures, the path of the production of various types of human capital over the labour market career is typically inferred from the path of wages, given estimated paths of prices or rental rates for the different types of human capital or skill.[5]

The original Mincer log wage equation used as independent variables years of schooling and years of experience.[6] After entry into the labour market years of schooling are constant, so that schooling mainly plays the role of a measure of human capital stock at the time of labour market

[3]This literature includes Heckman, Lochner and Taber (1998) and Bowlus and Robinson (2012), as well as a substantial literature concerned with skill biased technical change, leading to a constant elasticity of substitution (CES) framework with (at least) two types of general human capital, identified by education level, recently called the "canonical model" by Acemoglu and Autor (2011). See, for example, Bowlus et al. (2023), and the references therein.

[4]Recently, some direct measures at the individual level of the stock of skills used on the job have appeared. However, evidence in Bowlus, Robinson and Trivieri (2024) suggests that differencing such measures to generate an estimate of human capital production output over a period does not perform well relative to the innovative output measure in LISA used in this paper.

[5]See Bowlus and Robinson (2012).

[6]See Mincer (1974)

entry. Years of experience play the role of capturing the net additions to the stock of human capital rented to the market during the post schooling period. At a minimum a quadratic specification for experience is specified to allow for a concave shape implied by theories of optimal life-cycle investment, such as Ben Porath (1967). A major disadvantage of the original measures used in the Mincer log wage specification is that individuals are distinguished only by their years of schooling and years of experience. There is strong evidence, however, that there is a large amount of individual variation in both the stock of human capital on labour market entry, and changes in that stock (investment levels) over time within education and experience groups. In response to this, other independent variables have been added to capture this individual variation within schooling and experience category. These include measures of "ability" that capture individual variation in some initial human capital stock or in the ability to produce human capital over the lifecycle.[7] For the post schooling period the availability of long panels in the US has also lead to inclusion of measures of firm, industry and occupation tenure to proxy for investment in various types of specific human capital, contrasting with general human capital proxied by experience. However, as with experience, the tenure measures do not provide individual levels of investment within tenure.

3 Human Capital Measures in LISA

LISA is a rich panel survey that collects information from 34,000 Canadians aged 15+ about their jobs, education, health and family. It spans the years 2012-2020 on a biennial basis and contains monthly labour market histories along with standard wage and worker characteristics. The information on educational achievement in LISA is used to define three "types" of human capital identified with three education levels: (1) high school graduate and below; (2) some college or university beyond high school; (3) BA degree or higher. Measures of experience are derived from the labour market histories in LISA and represent actual rather than "potential" experience.

[7] In addition, there is also evidence for variation in rental rates faced by individuals based on characteristics such as sex, race, immigration status, etc. Regression models also include race and sex to address issues of discrimination that may lead to variation in the rental price for human capital across individuals. Neal and Johnson (1996) use the Armed Forces Qualifying Test (AFQT) as a measure of pre-market skills; Hanushek et al. (2015) uses a Program for the International Assessment of Adult Competencies (PIAAC) score in an international study of returns to skill.

3.1 Direct Post School Human Capital Production Output Measure

The most novel skill questions in LISA are those that ask for a self reported summary measure of the respondent's skill change over time, and follow up questions on how the individual produced the skill change. Once heterogeneous human capital is allowed within a limited number of types of human capital defined by education group, the optimal life-cycle human capital investment problem becomes complicated. Retaining the simplifying assumption that the objective is to maximize the discounted sum of lifetime earnings, the individual now has to solve for an optimal path of a portfolio of stocks with different prices instead of a single stock with a single price. There is no longer the evolution of a single stock that is proportional to earnings via a single price. We assume that the individual "solves" this problem by potentially increasing some stocks while letting others decline via depreciation, and that the answers given in the summary skill change questions in LISA are informative about the direction and magnitude of the optimal portfolio. This direct measure of the output of post schooling human capital production has the disadvantage of being a self reported, rather than an objective measure of skill change. However, there is no set of direct objective measures for changes to a portfolio of skills at different points in a worker's career. Moreover, the very limited number of direct objective measures used to evaluate the output of on-the-job training programs are restricted to a narrow group of very specific skills.[8]

In LISA, there are two questions dealing with the amount and direction of skill change, which are asked in all waves starting in 2014. First, respondents are asked : "Thinking about the skills you use on your current job, would you say that your skills have changed over the last two years?" If the answer is "yes", respondents are then asked:

"Has your skill level ...?"

1. Decreased (for example, memory is worse so tasks take longer; manual dexterity is not as good as before; I generally find it harder to achieve as much as I did before)
2. Increased somewhat (for example, I do things a little more quickly; I can do things at a higher level than I could before; I can do new things)
3. Increased a lot (for example, I am much better at my job; I have learned a lot more; I can do many more things, or some new things at a higher level)

[8] See Black, Skippers and Smith (2023), Table 8.

Table 1: Skill Change by Education and Experience

	Years of Experience				
	< 8	$[8, 16)$	$[16, 25)$	$[25, 35)$	$35+$
			Low Education		
Males					
No Skill Change	34.70	35.42	47.72	56.16	66.90
Small Skill Increase	29.84	31.62	29.32	27.29	21.34
Large Skill Increase	35.46	32.97	22.96	16.56	11.76
Females					
No Skill Change	38.49	45.46	57.97	59.96	57.75
Small Skill Increase	28.62	29.07	22.51	23.76	22.50
Large Skill Increase	32.89	25.47	19.52	16.28	19.75
			Mid Education		
Males					
No Skill Change	30.44	31.23	45.53	45.57	55.96
Small Skill Increase	23.87	33.17	30.88	33.23	29.97
Large Skill Increase	45.69	35.59	23.59	21.20	15.07
Females					
No Skill Change	38.07	42.30	46.11	50.18	53.96
Small Skill Increase	31.10	27.01	29.30	29.86	27.69
Large Skill Increase	30.83	30.69	24.58	19.95	18.34
			High Education		
Males					
No Skill Change	21.44	31.96	39.81	50.34	58.94
Small Skill Increase	32.86	40.36	37.26	34.81	31.60
Large Skill Increase	45.70	27.68	22.93	14.85	9.46
Females					
No Skill Change	30.05	36.05	37.66	43.00	47.51
Small Skill Increase	32.13	37.71	35.57	37.13	36.33
Large Skill Increase	37.83	26.25	26.78	19.88	16.16

Optimal life-cycle human capital accumulation models generally predict show a concave life-cycle profile with large early production levels that decline over the life-cycle. The basic human capital framework also suggests that the amount of investment is higher for individuals with higher levels of education. Table 1 reports the patterns for the three production (output) levels constructed from the LISA questions: (1) no skill change; (2) small skill increase; (3) large skill increase.[9] The results in Table 1 show the expected decline in production levels by experience for all groups: the fraction reporting no skill growth increases with experience, while the fraction reporting large skill growth decreases. Table 1 also shows generally higher production levels for the higher education groups.

3.2 Direct Post School Human Capital Production Input Measures

For all the individuals that report any positive skill change in the summary measure, follow up questions are asked to identify the particular form or forms of human capital investment that were undertaken to increase their skill. All the individuals that report that their skill increased "somewhat" or "a lot" are subsequently asked to respond "yes" or "no" to a series of ten questions of the form: "How did your skill level increase? - NAME OF ACTIVITY". The "activities" are: 1) Workshops, tutorials and seminars [made available by your employer]; 2) Computer assisted, correspondence or online training [made available by your employer]; 3) Self-Study; 4) Practice; 5) Being shown how to perform a task; 6)Being assigned to work with someone for instruction or guidance; 7) Reading manuals, training notes or other materials; 8) Acquiring knowledge or skills relevant to a job through discussions or meetings; 9) Other training you received outside of your employer; 10) Formal Education; and 11) Other. If a respondent answers yes to more than one of the questions in the series, they are then asked to indicate which of these activities was most important for increasing their skill.

We construct a primary activity or skill investment type for each individual from the these activities. This is defined as the single activity for individuals reporting only one, and as the activity that was most important for individuals reporting more than one. While the basic human capital framework provides expected patterns for amounts of investment (inputs) over time across groups,

[9]The "no skill change" category includes a very small number of reported skill decreases. The reporting restrictions at the Statistics Canada Research Data Centre that houses LISA do not allow for separate reporting of results for very small samples. LISA also has measures of a variety of job skills that can be differenced in the panel for each job skill to give alternative output measures. However, Bowlus, Robinson and Trivieri (2024) show that, unlike the summary skill change measure, these do not pass the test of a good output measure in the sense that they do not do well in explaining wage growth.

it provides little guidance on the expected pattern of variation in the *types* of inputs used and their patterns over a worker's career. Within the spirit of the framework, the structure in the production functions and input prices determining costs together with rental rates for the human capital types jointly determine input and output choices. The three human capital types, defined by education level, may be more efficiently produced by different input forms, and the optimal input forms may change over the life-cycle.

The patterns across experience groups of each of the primary activities, asked only of employees who reported positive skill change, are very similar for males and females within each education group. Table 2 presents the pooled male and female results.[10] The primary activity "Practice" is the most common form of skill increasing activity for all education groups. It declines with experience for all education groups, but still remains the most common for those with 35 or more years of experience. For the earliest experience group, 43% of the low education group have this as their primary activity - a much higher percentage than for any other activity. Similarly, for the mid and high education groups, 37% of the earliest experience group have this as their primary activity. The combination of the activities "Being shown how to perform a task" and "Being assigned to work with someone for instruction or guidance" is also a common form of skill increasing activity. It also declines with experience for all education levels. While these are in some ways similar activities, "Being assigned to work with someone for instruction or guidance" suggests applications to more complex tasks. The patterns in Table 2 show that, while both activities are primary activities in roughly equal proportions for the low education group, for the mid and high education groups "Being assigned to work with someone for instruction or guidance" is much more important. The activities "Self-study" and "Reading manuals, training notes or other materials" are much less common activities early on, but show a different pattern by experience. They grow with experience for all education groups, so that by the oldest experience group they become important for those continuing to increase their skills. Another activity that increases as a proportion with experience is "Acquiring knowledge or skills relevant to a job through discussions or meetings." This is especially important for the high education group where, as a proportion, it peaks for the mid experience group and remains high.

The activities "Formal education" and "Other training you received outside of your employer" are much less common. Formal education, as a percentage of the total still increasing their skills

[10]The relatively short panel in LISA does not permit a detailed analysis of the evolution of primary activities for the same individual. The patterns identified across experience groups in Table 2 are therefore not necessarily the same pattern that would be seen if a cohort of individuals could be followed over their full life-cycle.

Table 2: Primary Skill Increasing Activity by Education and Experience

	Years of Experience				
	< 8	$[8, 16)$	$[16, 25)$	$[25, 35)$	$35+$
			Low Education		
Workshops	4.25	7.96	8.32	11.55	13.38
Online	2.74	5.33	4.55	9.40	7.49
Self-Study	7.26	7.79	10.48	10.07	11.49
Practice	43.06	41.20	37.16	32.02	27.02
Being shown	13.74	10.68	13.32	7.76	7.25
Work with others	14.67	12.13	7.49	8.65	7.35
Reading manuals	1.73	3.21	2.97	5.98	5.14
Discussion	5.77	6.51	11.80	11.81	16.59
Outside training	1.70	2.27	2.92	2.36	4.28*
Formal education	5.08	2.91	1.00	0.39	-*
			Mid Education		
Workshops	9.40	10.94	12.52	13.26	14.85
Online	3.87	3.79	8.13	7.05	9.01
Self-Study	7.49	9.34	10.25	12.80	10.96
Practice	36.70	34.80	28.23	25.37	22.02
Being shown	7.02	7.54	7.95	6.55	6.09
Work with others	17.28	10.78	8.52	8.80	7.59
Reading manuals	2.77	3.07	5.15	5.55	7.13
Discussion	5.14	12.07	13.25	14.43	17.80
Outside training	2.95	3.73	3.75	3.76	3.57
Formal education	7.39	3.95	2.25	2.42	0.97
			High Education		
Workshops	12.19	13.27	12.29	16.32	15.89
Online	3.31	5.14	4.92	5.29	6.80
Self-Study	9.24	12.70	14.23	14.48	14.32
Practice	37.05	32.06	29.58	26.80	26.08
Being shown	5.64	3.97	3.69	4.34	3.64
Work with others	11.30	6.80	6.21	4.13	3.68
Reading manuals	2.74	3.01	4.08	6.02	5.58
Discussion	10.87	17.30	18.68	16.67	16.45
Outside training	3.24	2.71	4.17	2.94	4.89
Formal education	4.41	3.03	2.13	3.01	2.67

Notes:
Columns sum to 100.
*Outside training and Formal education combined.

tends to decline with experience while other training increases. Two activities explicitly identified as being made available by the employer, "Workshops, tutorials and seminars [made available by your employer] and "Computer assisted, correspondence or online training [made available by your employer]" also increase with experience as a fraction of those still increasing their skill, though the increase is small for the high education group.

Overall, there appears to be a major role played by relatively informal forms of skill acquisition. The activity "Practice" may be associated with "learning-by-doing" and may be suggested by the specific wording in the skill increase questions such as: "for example, I do things a little more quickly" or "for example, I am much better at my job."[11] Another relatively informal activity is "Being assigned to work with someone for instruction or guidance." This activity suggests a form of employer behaviour that selects workers considered promising enough for advancement, though in some cases employees may request such assignment. Similarly, the activities that tend to increase as a proportion with experience, "Self-study" and "Reading manuals, training notes or other materials" and "Acquiring knowledge or skills relevant to a job through discussions or meetings" are relatively informal. The explicitly formal training forms "Workshops, tutorials and seminars [made available by your employer] and "Computer assisted, correspondence or online training [made available by your employer]" are always a relatively small fraction of the total. Thus, measures of formal training may only capture a small fraction of total on-the-job training in the sense of post schooling investment over the life-cycle.

3.2.1 Access to Training Made Available by Employers

While all workers can invest in their skills through more informal activities, such as self-study, not all workers are offered more formal skill training by their employers. Following the questions asking about the activities respondents used to increase their skills, further questions are also asked in all the waves starting in 2014 that focus on the first two of the forms of the inputs (activities) explicitly identified as being made available by the employer: Workshops, tutorials and seminars WTS) and Computer assisted, correspondence or online training (CCO). First, respondents aged 18 and older who were paid employees during the reference week and who did *not* indicate a skill level increase from WTS over the past two years in the previous set of questions were asked: "Over the last two years, have you taken any workshops, tutorials or seminars made available by your employer?" If

[11] It could also involve practicing without producing any actual output.

Table 3: Offer and Take-up Rates (%) and Average Duration (hours) for WTS and CCO for Males

	WTS			CCO		
	1	**2**	**3**	**4**	**5**	**6**
	Offer Rate	**Take-up Rate**	**Average Hours**	**Offer Rate**	**Take-up Rate**	**Average Hours**
				Low Education		
Exp < 8	43.31	86.82	123.56	37.67	90.57	132.21
Exp $[8, 16)$	45.09	89.86	84.86	34.88	83.59	97.73
Exp $[16, 25)$	50.97	89.87	60.75	34.10	84.67	87.55
Exp $[25, 35)$	47.70	87.41	78.62	28.94	87.00	100.17
Exp 35+	41.74	87.68	35.94	25.93	87.60	47.50
				Mid Education		
Exp < 8	50.12	90.60	219.34	36.66	83.16	295.70
Exp $[8, 16)$	56.57	93.23	130.73	46.51	91.83	136.81
Exp $[16, 25)$	62.39	91.30	61.21	46.63	91.17	74.60
Exp $[25, 35)$	63.50	91.57	62.52	52.02	89.65	71.25
Exp 35+	61.06	93.13	66.70	50.22	85.62	83.68
				High Education		
Exp < 8	74.36	92.27	188.14	60.44	83.52	229.38
Exp $[8, 16)$	79.06	92.00	91.80	64.78	81.85	84.17
Exp $[16, 25)$	75.64	92.76	89.62	64.69	85.98	93.51
Exp $[25, 35)$	75.24	91.06	98.28	64.05	87.93	99.75
Exp 35+	64.33	89.10	59.95	57.57	86.42	45.89

Notes:
WTS: Workshops, tutorials and seminars [made available by your employer]
CCO: Computer assisted, correspondence or online training [made available by your employer]

the respondent answers "No", they are then asked "Were you offered any?". These were repeated for CCO. Thus, we are able to construct variables that indicate if the respondent chose as inputs either or both of the two activities WTS and CCO for all paid employees 18+ that were working in the reference week. For those that did not choose to take WTS or CCO or both, we know whether they were offered and so can distinguish between whether they were offered but chose not to take them, or whether they were not offered and hence could not take them. This appears to be a unique feature of the LISA data set. Black, Skipper and Smith (2023), who survey published papers and present their own new research on participation in training programs, do not discuss offer or take-up rates. Since the worker can choose an employer, in principle the worker is also choosing whether various skill investment choices are offered. For simplicity, in this paper we consider the menu of activities offered by the employer as exogenous, and hence as an independent variable in explaining variation in input type.

Tables 3 and 4 report, the fraction of workers offered the training (offer rate), and the fraction of

Table 4: Offer and Take-up Rates (%) and Average Duration (hours) for WTS and CCO for Females

	WTS			CCO		
	1	**2**	**3**	**4**	**5**	**6**
	Offer Rate	**Take-up Rate**	**Average Hours**	**Offer Rate**	**Take-up Rate**	**Average Hours**
				Low Education		
Exp < 8	42.94	91.28	120.57	36.60	93.53	134.13
Exp $[8, 16)$	43.84	91.51	87.45	34.59	93.18	84.97
Exp $[16, 25)$	41.64	89.48	58.25	37.29	85.44	49.04
Exp $[25, 35)$	52.27	89.62	74.50	39.89	84.33	88.95
Exp 35+	50.57	89.80	67.27	32.89	87.80	76.97
				Mid Education		
Exp < 8	56.53	93.16	109.30	43.10	86.69	152.32
Exp $[8, 16)$	59.83	93.74	153.27	43.10	90.82	159.73
Exp $[16, 25)$	63.63	93.01	95.52	49.69	89.75	94.21
Exp $[25, 35)$	60.50	93.50	106.36	49.99	88.59	117.68
Exp 35+	61.71	91.36	60.97	53.42	88.49	74.90
				High Education		
Exp < 8	69.82	92.23	100.53	53.84	84.88	124.57
Exp $[8, 16)$	75.00	93.74	92.32	59.58	83.49	112.51
Exp $[16, 25)$	79.94	94.39	73.11	63.07	86.93	75.05
Exp $[25, 35)$	77.68	93.01	84.86	66.35	87.14	80.38
Exp 35+	71.11	95.20	45.57	63.38	86.77	46.15

Notes:
WTS: Workshops, tutorials and seminars [made available by your employer]
CCO: Computer assisted, correspondence or online training [made available by your employer]

those that took up the training (take-up rate) for WTS (columns 1 and 2) and CCO (columns 4 and 5), by education, sex and experience, for males and females, frespectively. The offer rates are much higher for the high education group. For example, for the mid experience group, ($[8, 16)$) years, the offer rates of WTS for males (Table 3) increase from 50.97% for the low education group, to 62.39% for the mid education group and to 75.64% for the high education group. For females (Tanle 4) there is a similar pattern of increase from 41.64% to 63.63% to 79.94%. To the extent that both workers and firms have less incentive to invest in training as worker experience increases, predicted by the framework of Section 2, the patterns of take-up rates and, perhaps, offer rates, are expected to show a decline with experience. In fact, this is not apparent; the rates are quite stable. However, it is possible that the main margin over which workers adjust their total investment in training, also consistent with the framework of Section 2, is through the "intensive margin" or number of hours invested. Workers may still take training opportunities, but spend less time in the training.

Workers who took WTS and/or CCO were asked about the length of the training. They were

told to include only the time actually spent in training sessions and they could report either hours or days. We constructed a measure of hours of training for all workers by converting the responses reported in days to hours using a conversion rate of 8 hours for each day. Columns 3 and 6 in Tables 3 and 4 report the average training hours for the sample of workers who take up training in WTS and CCO, respectively.[12] The results for average hours do show the expected pattern of a decline with experience for both males and females and for all education groups. Average hours spent in training for those workers that take up either WTS or CCO decline from the lowest experience group to the highest experience group in all cases. The decline is typically at least 50%.[13]

While the offer rates are relatively high for the high education group, these types of formal employer provided training are not offered to all workers. One possibility is that for small employers it may not be feasible to offer training, or that costs per worker of providing this kind of training may be higher. To provide some evidence on this, we estimate a linear probability model (LPM) with the offer rate as the dependent variable and firm size, education, sex and experience as independent variables. The estimated coefficients are reported in Table 5. Firm size has a strong and significant effect on the probability of training being made available by employers. Training opportunities provided by the largest employers (1,000 or more employees) are 12.36% more likely for WTS and 15.45% more likely for CCO compared to the smallest employers (less than 50 employees). The results in Table 5 show significantly higher offer rates for the high education group with a 8.94% higher probability of being offered WTS and a 12.34% higher probability of being offered CCO compared to the low education group. This result reflects the more detailed patterns in Tables 3 and 4. Table 5 also shows only minor differences by sex, again, reflecting the more detailed patterns in Tables 3 and 4. There is a small, marginally significant negative effect of being female for WTS and no effect for CCO, providing little evidence to support the existence of employer discrimination against women in the provision of training opportunities. In contrast, non whites do show significantly negative effects for both WTS (-4.61%) and CCO (-5.56%).

[12]For the sample of workers who took WTS, it is not possible to separately identify the hours for WTS alone if they also took CCO; similarly for the sample of workers who took CCO, it is not possible to separately identify the hours for CCO alone if they also took WTS. In fact, taking WTS without CCO or vice versa is not common; most workers took both. Thus the average hours in column 3 will also include some hours in CCO, and the average hours in column 6 will also include some in WTS.

[13]While the decline from the lowest experience group to the highest experience group in all cases is strong, it is not monotonic, which may reflect the noisy aspect of the measures for WTS and CCO individually noted in the previous footnote.

Table 5: Determinants of the Offer Rates of WTS and CCO

Dependent Variable:	**Probability WTS Offered**	**Probability CCO Offered**
Firm Size $[50, 250)$	0.0391***	0.0579***
	(0.0106)	(0.0086)
Firm Size $[250, 1000)$	0.0704***	0.0795***
	(0.0165)	(0.0123)
Firm Size 1000+	0.1236***	0.1545***
	(0.0245)	(0.0197)
Mid Education	0.0099	0.0259***
	(0.0094)	(0.0075)
High Education	0.0894***	0.1234***
	(0.0131)	(0.0105)
Female	-0.0169*	-0.0037
	(0.0090)	(0.0074)
non white	-.0461***	-0.0568***
	(0.0105)	(0.0081)
Exp $[8, 16)$	0.0030	0.0119
	(0.0127)	(0.0108)
Exp $[16, 25)$	0.0128	0.0072
	(0.0137)	(0.0109)
Exp $[25, 35)$	0.0169	0.0123
	(0.0131)	(0.0107)
Exp 35+	-0.0015	0.0065
	(0.0134)	(0.0108)
constant	0.0756***	0.0348***
	(0.0104)	(0.0081)
N	10900	14700
R^2	0.033	0.059

Notes:
WTS: Workshops, tutorials and seminars [made available by your employer]
CCO: Computer assisted, correspondence or online training [made available by your employer]
Omitted category is low education males with less than 8 years experience.
Standard errors in parentheses.
$* \ p < 0.1$, $* * \ p < 0.05$, and $* * * \ p < 0.01$.

Table 6: Probability of Large Skill Production and Primary Activities

	Male			**Female**		
	1	**2**	**3**	**4**	**5**	**6**
	Low Education	**Mid Education**	**High Education**	**Low Education**	**Mid Education**	**High Education**
WTS	0.0423	-0.0617**	-0.0531*	0.0614	0.0171	-0.0556**
	(0.0362)	(0.0308)	(0.0315)	(0.0388)	(0.0279)	(0.0260)
CCO	0.0814	0.0471	0.0320	0.0244	0.0109	0.0702
	(0.0505)	(0.0395)	(0.0442)	(0.0435)	(0.0362)	(0.0440)
Self-study	0.0904***	0.1033***	0.0012	0.0156	0.0467	-0.0168
	(0.0325)	(0.0301)	(0.0290)	(0.0412)	(0.0330)	(0.0301)
Shown	0.0729**	0.0747*	-0.0071	0.0013	-0.0209	-0.0791**
	(0.0298)	(0.0383)	(0.0507)	(0.0296)	(0.0314)	(0.0388)
Assigned	0.1598***	0.1106***	0.1323***	0.1205***	0.1288***	0.0733**
	(0.0292)	(0.0309)	(0.0387)	(0.0319)	(0.0310)	(0.0339)
Manuals	0.0840	0.0128	-0.0277	0.0929	0.0313	0.0422
	(0.0518)	(0.0391)	(0.0490)	(0.0601)	(0.0450)	(0.0459)
Discussion	-0.0070	-0.0067	0.0196	0.0068	0.0409	-0.0270
	(0.0339)	(0.0293)	(0.0290)	(0.0365)	(0.0291)	(0.0261)
Outside	0.1476**	0.0555	-0.0126	0.1024	0.0548	0.0686
	(0.0608)	(0.0462)	(0.0523)	(0.0686)	(0.0488)	(0.0499)
Formal Ed	0.1366**	0.1613***	0.1616***	0.2515***	0.2717***	0.2236***
	(0.0567)	(0.0550)	(0.0543)	(0.0518)	(0.0461)	(0.0454)
Exp $[8, 16)$	-0.0014	-0.0544*	-0.1403***	-0.0494*	0.0117	-0.0858***
	(0.0295)	(0.0282)	(0.0282)	(0.0278)	(0.0247)	(0.0228)
Exp $[16, 25)$	-0.0943***	-0.1438***	-0.1517***	-0.0596*	-0.0448*	-0.0977***
	(0.0289)	(0.0273)	(0.0273)	(0.0329)	(0.0245)	(0.0232)
Exp $[25, 35)$	-0.1777***	-0.1722***	-0.2338***	-0.1238***	-0.0800***	-0.1781***
	(0.0275)	(0.0261)	(0.0281)	(0.0312)	(0.0245)	(0.0245)
Exp 35+	-0.2011***	-0.2221***	-0.3000***	-0.0780*	-0.1043***	-0.1753***
	(0.0291)	(0.0281)	(0.0354)	(0.0416)	(0.0317)	(0.0407)
constant	0.4920***	0.5342***	0.5267***	0.4826***	0.4675***	0.5101***
	(0.0159)	(0.0224)	(0.0233)	(0.0171)	(0.0198)	(0.0188)
N	3100	3200	2700	2700	3500	3400
R^2	0.042	0.043	0.052	0.023	0.022	0.033

Notes:
[1] Omitted category is Practice with less than 8 years experience.
[2] Full titles: Shown (Being shown how to perform a task)
Assigned (Being assigned to work with someone for instruction or guidance
Manuals (Reading manuals, training notes or other materials)
Discussion (Acquiring knowledge or skills relevant to a job through discussions or meetings)
Outside (Other training you received outside of your employer)
[3] Standard errors in parentheses.
[4] $* \ p < 0.1$, $* * \ p < 0.05$, and $* * * \ p < 0.01$.

4 Analysis of the Production Structure using the Input and Output Measures

In this section we conduct a descriptive analysis of the relationship between the new input and output measures available in LISA described in Section 3 and interpret the results within the framework of Section 2. The self reported skill change measure used in this section, described in Section 3, provides a unique, direct measure of training output at the individual level. It is observed for a large, random sample of all workers of varying education and experience levels in a wide variety of occupations. Of the fourteen published studies on the impacts of firm training surveyed in Black, Skipper and Smith (2023), almost all use wages or wage changes.[14] Of the two exceptions, only one has a direct measure at the individual level: this study looked at the effect on the average time to handle a call in a sample of 74 call centre workers of a one-week course on techniques to decrease time to handle calls without lowering call quality.[15] The other study did not have a direct measure, but used data at the industry level for 94 industry groupings and estimated the effect on value added per worker of job-connected education or training.[16]

4.1 Primary Activities and Skill Growth

The broadest set of input measures is the set of primary activities. The sample used in Table 2, can be divided into those that increased their skill "somewhat" and those that increased it "a lot". We estimate a LPM, separately for males and females and each education group. The dependent variable is equal to 1 if the skill growth was large, and zero otherwise. The independent variables are: (1) a set of dummy variables representing the primary activity used and (2) experience categories. The omitted group has less than 8 years of experience and uses the practice (the most common primary activity in Table 2) as the primary activity for increasing their skill. The estimated coefficients are reported in Table 6. There is, as expected from Table 1, a strongly significant pattern for experience with skill growth declining with experience. The use of practice by males at the start of their career (lowest experience level) is associated with a 49.20% probability that the investment produces a large skill increase in the population of low education workers reporting skill increases. The probabilities for the mid and high education levels are 53.42% and 52.67%, respectively. For the

[14] See Black, Skipper and Smith (2023), Table 8.
[15] De Grip and Sauermann (2012).
[16] Dearden, Reed and Van Reenen (2006).

highest experience group, these probabilities are reduced to 29.09%, 31.21% and 22.66% for the low, mid and high education groups, respectively. A similar pattern occurs for females, though there is a smaller reduction in the probabilities.

Table 2 shows that "Being assigned to work with someone for instruction or guidance" is the most common activity, after Practice, used to increase skill at the start of a worker's career. The results in Table 6 show that all types of workers declaring their primary activity responsible for increasing their skill as "Being assigned to work with someone for instruction or guidance" have significantly higher probabilities of their investment in training producing a large skill increase. For males the probabilities increase by 15.98%, 11.06% and 13.23%, for the low, mid and high education groups, respectively. For females the increases are 12.05%, 12.88% and 7.88%, respectively. This is consistent with the activity being a larger or more productive input chosen by the employee, but also with employers assigning more promising workers to better opportunities. Unfortunately, it is not possible from the available data to distinguish between these possibilities. No other relatively common activities identified in Table 2, such as "Acquiring knowledge or skills relevant to a job through discussions or meetings", have this general positive effect, relative to Practice. Formal education is not identified as being very common as a primary activity in Table 2, but when it is it increases the probability of a large skill increase relative to Practice for males as much as "Being assigned to work with someone for instruction or guidance." For females it has double the effect of "Being assigned to work with someone for instruction or guidance." Self-study and Other training received outside of your employer increase the probability of a large skill increase relative to Practice for low educated males. Self-study also increases the probability for males in the mid education group. For females there are no significant effects.

4.2 Training Made Available by Employers and Skill Growth

Skill changes for the full set of primary activities are available only for workers reporting positive skill growth and they do not contain any information on the length of the investment activity. The narrower set of activities, consisting of the more formal activities made available by the employer, WTS and OCC, are available for all workers and, as detailed in Section 3.2.1, for these activities it is possible to create a measure of the number of hours invested in the training. Typically, workers taking either WTS or CCO take both together. For this sample, the training hours measure refers

Table 7: Distribution of Skill Production Levels for Workers Taking WTS and CCO

	Male			Female		
	1	**2**	**3**	**4**	**5**	**6**
	No Skill Change	**Small Skill Change**	**Large Skill Change**	**No Skill Change**	**Small Skill Change**	**Large Skill Change**
			Low Education			
Exp < 8	13.22	34.41	52.37	19.03	33.45	47.52
Exp $[8, 16)$	9.14	42.14	48.72	24.30	44.90	30.79
Exp $[16, 25)$	28.82	35.61	35.57	34.47	35.25	30.29
Exp $[25, 35)$	25.07	38.68	36.25	33.27	38.51	28.21
Exp 35+	36.41	37.84	25.75	25.02	31.83	43.15
			Mid Education			
Exp < 8	16.85	21.79	61.37	17.16	37.96	44.88
Exp $[8, 16)$	16.36	37.22	46.42	25.94	31.98	42.08
Exp $[16, 25)$	29.71	36.15	34.14	24.51	35.50	39.99
Exp $[25, 35)$	26.70	47.98	25.32	31.22	38.35	30.43
Exp 35+	34.32	42.83	22.85	38.83	33.72	27.45
			High Education			
Exp < 8	13.34	34.16	52.50	18.10	43.14	38.76
Exp $[8, 16)$	21.62	46.99	31.39	23.39	48.37	28.24
Exp $[16, 25)$	31.14	40.88	27.98	29.75	40.89	29.36
Exp $[25, 35)$	39.39	40.32	20.28	28.18	46.06	25.77
Exp 35+	45.30	40.71	13.99	34.13	47.37	18.50

Notes:
WTS: Workshops, tutorials and seminars [made available by your employer]
CCO: Computer assisted, correspondence or online training [made available by your employer]

to the total for both WTS and CCO.[17] To provide evidence on the relationship between the input of training hours and the output of skill growth, Tables 7 and 8 report the distribution of skill growth and the associated average hours, respectively, by sex and education level, for all workers taking both WTS and CCO for five levels of experience.[18]

While a majority report skill growth, a substantial fraction of workers in Table 7 report no change in skill. The fraction reporting no skill change increases with experience for all groups. For low educated men it reaches 36.41% at 35 or more years of experience. For mid and high education level male workers it reaches 34.32% and 45.30%, respectively. For women the incidence at 35 or more years of experience is similarly high. This suggests that some of the training provided by employers is unproductive, or of too short a duration to produce a noticeable skill increase from the point of view of the employee.

[17] The separate WTS and CCO components of this total cannot be identified. For workers taking only WTS, the training hours measure refers only to WTS; similarly for workers taking only CCO, the training hours measure refers only to CCO. However, these samples are too small for disaggregated analysis.

[18] A very small number of outliers for training hours are excluded.

Table 8: Skill Production Levels and Hours of Training for Workers Taking WTS and CCO

	Male			**Female**		
	1	**2**	**3**	**4**	**5**	**6**
	No Skill Change	**Small Skill Change**	**Large Skill Change**	**No Skill Change**	**Small Skill Change**	**Large Skill Change**
			Low Education			
Exp < 8	64.84	68.47	142.44	54.17	68.43	105.28
Exp $[8, 16)$	62.75	113.22	133.00	40.03	50.66	124.28
Exp $[16, 25)$	71.03	95.41	127.27	41.47	62.96	105.66
Exp $[25, 35)$	51.31	58.61	177.42	54.15	40.36	93.29
Exp 35+	40.85	41.33	73.46	46.52	115.46	104.34
			Mid Education			
Exp < 8	63.43	75.08	179.35	49.07	73.02	110.49
Exp $[8, 16)$	44.17	122.80	160.54	37.95	38.96	120.17
Exp $[16, 25)$	35.62	79.14	117.80	42.46	46.53	124.62
Exp $[25, 35)$	54.98	82.70	97.93	40.79	109.37	108.32
Exp 35+	69.91	77.23	77.09	77.01	64.86	87.81
			High Education			
Exp < 8	68.75	117.56	135.76	60.97	92.29	106.94
Exp $[8, 16)$	46.79	80.20	110.45	56.89	68.44	115.95
Exp $[16, 25)$	56.87	72.53	118.21	49.11	47.16	91.82
Exp $[25, 35)$	46.93	74.97	141.73	45.92	56.38	118.50
Exp 35+	44.94	43.20	90.16	54.51	43.26	32.75

Notes:
WTS: Workshops, tutorials and seminars [made available by your employer]
CCO: Computer assisted, correspondence or online training [made available by your employer]

Table 8 shows the relationship between hours of training and skill growth. For almost all of the 30 combinations of education, sex and experience groups in Table 8 the duration of training for those reporting no skill increase is less than 2 weeks over a 2 year period. The average duration of the training for large skill increases, by contrast, is much larger, often 1-2 months. The duration of training for the smaller increases falls in between. There is a general pattern of more hours of training being associated with higher skill production. For males there is a consistent monotonic pattern between hours of training and skill growth for all experience and education groups.[19] For females, in most cases there is also a monotonic pattern. There are some cases for females where there are small deviations from monotonicity, but, with the exception of females in the high education group with 35+ years of experience, large skill production is still associated with higher hours than no skill change.

The sample in Table 8 consists of all workers taking both WTS and CCO; for many of these workers the primary activity for increasing their skill is neither WTS or CCO, so that the effect of variation in the training hours for WTS and CCO may have relatively "noisy" effects on the variation in skill growth.[20] Restricting the sample used in Table 8 to workers that took both WTS and CCO, and for whom either WTS or CCO was the primary activity would allow for a clearer link between skill growth and the variation in training hours in WTS and CCO. However, it substantially reduces the sample size. It removes workers reporting no skill growth, and from those with positive skill growth it removes those who do not use either WTS or CCO as their primary activity. Given the substantially reduced sample size, we examine the relationship between hours and skill growth in an alternative way that allows for less heterogeneity.

The restricted sample remains large enough to estimate a LPM model with a dependent variable equal to 1 if the skill growth was large, and zero otherwise and independent variables consisting of: (1) a set of dummy variables representing the quartiles of combined hours of training for WTS and CCO, and (2) dummy variables for education. The model is estimated separately for three experience categories: less than 8 years of experience, 8 to less than 25 years experience, and 25+ years of experience. The estimated coefficients are reported in Table 9. The omitted group are workers with low education that had combined hours of training for WTS and CCO of less than 40

[19]There are two very minor deviations from strict monotonicity in the point estimates for those with 35+ years of experience, but large skill production is still associated with higher hours than no skill change.

[20]Training made available by employers in the form of WTS and CCO is not commonly identified in Table 2 as the primary activity that workers use for increasing skill.

Table 9: Probability of Large Skill Production Using WTS and CCO with WTS or CCO as Primary Input

Dependent Variable:	**Large Skill Change**		
	Exp < 8	**Exp** $[8, 25)$	**Exp** $25+$
Training hours $[40, 350)$	0.2077**	0.1412***	0.1034**
	(0.0806)	(0.0448)	(0.0446)
Training hours 350+	0.4783***	0.2331*	0.4213***
	(0.1119)	(0.1326)	(0.0962)
Mid Education	0.0359	0.0117	-0.1702***
	(0.0994)	(0.0756)	(0.0615)
High Education	-0.1619*	-0.0925	-0.2119***
	(0.0911)	(0.0679)	(0.0638)
constant	0.4285***	0.3926***	0.4616***
	(0.0695)	(0.0625)	(0.0574)
N	300	700	700
R^2	0.103	0,034	0.056

Notes:
[1] Omitted category: low education, less than 40 hours training
[2] Standard errors in parentheses; clustered by ID.
[3] $* \ p < 0.1$, $* * \ p < 0.05$, and $* * * \ p < 0.01$.

hours in the last two years. For the lowest experience group, the omitted group has a probability of 42.85% of a large increase in skill in this sample of workers with positive skill growth. The effects of increasing training hours are large and highly statistically significant. The probability of a large skill increase goes up to 63.62% for those with between 40 and 350 hours of training, and to 90.68 for those with 350 or more hours of training. Clearly, for workers at the beginning of their career, investing in increased hours of training produce large increases in skills. The pattern is the same for workers in the middle and older experience groups, but the magnitudes are a little smaller. Thus, throughout a worker's career, skill production is possible through investing in training. There is little evidence of significant declining productivity of the training for older workers.[21]

[21]There is some evidence, especially for older workers, that the productivity of this kind of training declines for the higher education groups relative to the low education group. The pattern in Table 2 shows that WTS and CCO become relatively more important for the low education group as workers age compared to the higher education groups. One possibility is that this type of training introduces more novel features for the low education group, while for the higher education groups there is some element of repetition. However, it is not possible to distinguish this possibility from other potential explanations.

5 Conclusions

The means used by workers to increase their human capital over their career once they have left fulltime schooling and entered the labour market are not well understood. In this paper we use innovative measures available in LISA to construct new variables related to the production of skills in the post schooling period in a large panel. Examination of the primary methods used by employees to increase their skills suggests that relatively informal forms of skill acquisition, such as "Practice" or "Being assigned to work with someone for instruction or guidance", play a major role. Some activities that tend to increase in relative importance with experience, "Self-study" and "Reading manuals, training notes or other materials" and "Acquiring knowledge or skills relevant to a job through discussions or meetings" are also relatively informal. Conventional measures of more formal firm training may, therefore, only capture a small fraction of total on-the-job training in the sense of post schooling investment over the life-cycle.

For the two activities explicitly identified as being made available by employers, "Workshops, tutorials and seminars [made available by your employer]" and "Computer assisted, correspondence or online training [made available by your employer]", we exploit information on offer and take-up rates that we believe are unique to LISA. From our analysis of this information we present new evidence on several issues of interest. The probability of being offered such training depends on firm size and education level: workers at larger firms and those with higher education levels are more likely to be offered training. Non-white workers have a lower probability of being offered training. Take up rates for training offered by employers are generally high and neither offer rates or take up rates decline with experience. However, the pattern of declining average hours of training suggests that main margin over which workers adjust their total investment in training is through the intensive margin or number of hours invested. Older workers may still be offered and take up training opportunities, but spend less time in the training.

Evidence on the productivity of the different means used by workers to increase their skill is provided by examining the relationship between the different kinds of inputs (training activities) and an innovative, self reported measure of skill growth representing the output. There is a strongly declining probability of large skill growth with experience. "Being assigned to work with someone for instruction or guidance" is the most common activity, after "Practice", used to increase skill at the start of a workers career. All types of workers declaring their primary activity responsible

for increasing their skill as "Being assigned to work with someone for instruction or guidance" have higher probabilities of their investment in training producing a large skill increase. This is consistent with the activity being a larger or more productive input chosen by the employee, but also with it being employers assigning promising workers to better opportunities. Unfortunately, it is not possible from the available data to distinguish between these possibilities.

For workers taking the training activities explicitly identified as being made available by employers, a substantial fraction report no change in skill. This suggests that some of the training provided by employers is unproductive, or of too short a duration to produce a noticeable skill increase from the point of view of the employee. Observations on training hours for this group shows a duration of less than 2 weeks over a 2 year period. The average duration of the training for large skill increases, by contrast, is often 1-2 months. Among workers using the training activities explicitly identified as being made available by employers as their primary activity for increasing their skill, more hours of training are strongly associated with higher skill production.

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