PROBLEM SOLVING IN TECHNOLOGY-RICH ENVIRONMENTS, ADULT EDUCATION AND TRAINING, AND INCOME: AN INTERNATIONAL COMPARISON USING PIAAC DATA

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ABSTRACT: The high dependence on technology for economic activities in developed countries stresses the importance of lifelong learning in order to equip adult workers with the skills required to perform work related tasks, and also increase labor force participation. We use data from the 2012/2014 Program for the International Assessment of Adult Competencies (PIAAC) to examine relationships among problem solving skills in technology-rich environments (PSTRE), participation in adult education and training (AET), and income in Australia, Finland, Japan (high PSTRE scoring countries), Chile, Greece (low PSTRE scoring countries), Ireland, Estonia, and the United States (similarly scoring countries). Although PIAAC measured literacy, numeracy, and PSTRE skills, our research focus is on PSTRE because of its emphasis on problem-solving skills and critical thinking. These skills are undoubtedly important in any global economy currently experiencing rapid technological transformation. In four of five age groups, Japan had the highest PSTRE scores. With the exception of Greece, PIAAC respondents in the oldest age group had lower PSTRE scores than younger age groups. Men had higher PSTRE scores than women in all countries except Australia and Greece. Overall, those with higher PSTRE scores were more likely to participate in AET but there were variations by age, income, and education categories. Greater PSTRE scores were associated with higher hourly wages in the U.S. Australia and Estonia whereas no significant association was observed in other countries. With limited availability of data, females benefited financially from higher PSTRE scores more than males in the U.S., Finland, Ireland and Japan.

Keywords: PIAAC, problem solving skills, adult education and training

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Lack of basic skills (e.g., literacy, numeracy, and problem-solving skills) among the working-age population often results in high rates of unemployment and poverty, and in turn, can lead to an increased burden on the state due to high demand for social welfare programs (OECD, 2012). This underscores the importance of human capital such as basic and job-related skills for the economic stability of any society. Nonetheless, the value of the skills people in the labor force possess is hardly constant; individuals need to regularly upgrade their skills when and where necessary if they are to optimally perform in a labor market that is rapidly evolving (OECD, 2012). One such evolution is seen in the technologizing of various workplace processes (Cummins, Yamashita, Millar, & Sahoo, 2019; Hämäläinen, De Wever, Nissinem, & Cincinnato, 2019). The need for continuous learning for adult workers is necessary in order to boost their capacity to compete for and perform some of the available jobs.

Jan Tinbergen's popular analysis on how wage inequality results from technological advancements and increased education attainment (Martin, 2018) relates to our study. High use of technology in most economic activities in developed countries means there is an increased demand for skilled labor which can only be supplied through education and training. The fact that not enough workers have required skills for technology-rich jobs is an indication that educational systems are inadequately supplying the high skilled labor demanded by employers (Goldin & Katz, 2009; Martin, 2018). This imbalance between the demand and supply of skilled workers shows that a relatively small portion of workers have the skills required to perform certain work tasks in technology-rich environments, thus, resulting in income inequality. Put simply, the only way to reduce inequalities is to increase the supply of educated workers (Goldin & Katz, 2009). Thus, the reason our study is focused on problem solving skills in technology-rich environments (PSTRE), adult education and training (AET), and income is to better understand disparities in income and in participation in AET to inform policy and practice, all in an effort to reduce inequalities.

Technology and the need for adult education

One major way of generating income is through labor force participation. However, more work is expected to become automated due to technological advances and this is likely to reduce the number of available jobs in developed countries (Cummins et al., 2019; Hämäläinen et al., 2019). This industrial transformation may be problematic for adult workers who are unfamiliar with the importance of technology-rich environments for everyday activities (Button, 2019; Hämäläinen et al., 2019), and low skilled workers tend to be more affected by this rapid change in workplace processes than high skilled workers (Frey & Osborne, 2017). Also, examining the preparedness of aging workers to handle work tasks in a technology-rich environment in the workplace may show that employers are less likely to train older workers compared to younger workers because of the fear of poor return of the high cost of investment in training (Martin et al., 2014). This issue is likely worse for older female workers because

of a combination ageism and sex discriminations (Lain, Airey, Loretto, & Vickerstaff, 2018; Lössbroek & Radl, 2018).

Possessing higher levels of education and access to training may be associated with increased problem-solving skills in technology rich environments (PSTRE) because of the basic skills (i.e., literacy, numeracy, PSTRE) acquired to help navigate technology-rich environments (Howard et al., 2001). However, lack of training opportunities for some workers, particularly older workers (Lössbroek & Radl, 2018), may render them inadequately prepared to duly perform some specialized tasks in a technology-rich work environment. Thus, it is reasonable to assume that adult education and training which will help to increase PSTRE may also increase labor force participation rate.

Yalcin (2019) used data from the Program for the International Assessment of Adult Competencies (PIAAC) for 20 countries to compare PSTRE skills for men and women. Between men and women, there was very little difference in PSTRE scores and both genders face similar difficulties with information and communication technology tests (Yalcin, 2019). This narrow skill gap between genders may be as a result of the increase in education and work experience of women (Card, Cardoso, & Kline, 2016), but it also stresses the importance of education and lifelong learning towards skills development and improvement. Another study using PIAAC data found that factors such as age, higher levels of education, health status, and learning strategies (relating ideas to real life) predicted AET participation (Patterson, 2018).

Technology use is a challenge to some adult workers (e.g., older workers) who struggle with how to learn or use technological devices such as computers and their applications (Selwyn et al., 2003). Consequently, lack of resources (e.g., family responsibilities, low income, time management) coupled with poor technology use may impede education and training of some adult workers as most formal education and trainings are becoming more technology based. An example is offering online classes as a good source of lifelong learning for adult workers (Mason, 2006).

Because of the importance and influence of technology beyond the workplace to other aspects of everyday life, our study, using PIAAC data, is focused on problem solving skills in technology-rich environment (PSTRE) and its relationship with adult education and training (AET). We also examined the association between income and PSTRE, and if these associations vary among specified OECD countries. Our comparative study may help inform local and foreign policies that address issues of lifelong learning, labor force participation, and income.

***Research questions*.** To better understand the relationship between AET, income, and PSTRE scores, we used PIAAC data from Australia, Finland, Japan (high PSTRE average scores), Ireland, Estonia, the United States (similar average

PSTRE scores to the U.S.), Chile, and Greece (low average PSTRE scores). These countries were selected because of their geographic and economic diversity along with their variability in PSTRE scores. The research questions that were examined include:

1) What are the patterns of PSTRE scores by sex and age group?
2) Is there a relationship between participation in AET and PSTRE scores and does it vary by age group and sex?
3) Are the PSTRE scores and AET participation associated with hourly wages, and do the associations vary by age group and sex?

Data Sources and Methods

We use data from the 2012/2014 PIAAC from Australia, Finland, Japan, Ireland, Estonia, the United States, Chile, and Greece, to examine relationships among AET, hourly wages, PSTRE, sex, age and education in three groups of countries with different PSTRE scoring features (high, low and similar). PIAAC was organized by the Organization for International Cooperation and Development (OECD) and implemented by member nations. In the present study, we considered all conventional working-age respondents younger than 66 years old. PIAAC uses a complex sampling design to provide nationally representative data (Australian Bureau of Labor Statistics, 2013; NCES, 2016; OECD, 2014, 2016). The present study incorporates such complex sampling design in both the descriptive analysis and regression analysis. In the present study, we considered all respondents younger than age 66 in the numerical summary exploration of the data while we implemented regression analysis to the subset of employed respondent among them, due to the missing hourly wage information for the unemployed participants. Therefore, the resulting number of observations presented in the analysis results would be different for these two parts of analysis.

Measures. In PIAAC, the PSTRE survey questions focused on the abilities to "solve problems for personal, work and civic purposes by setting up appropriate goals and plans, accessing and making use of information through computers and computer networks" (Rouet et al., 2009, p. 9). PSTRE scores were obtained using multiple imputation of unobserved characteristics, ranging 0 to 500, with higher values indicating stronger problem solving skills. AET participation (1 = yes, 0 = no) indicates whether the respondent participated in adult education and training in the 12 months preceding the survey. Sex (1 = female; 0 = male), age groups (24 or younger, 25 – 34, 35 – 44; 45 – 54; 55 – 65) were coded as a binary variable and logged hourly wages in U.S. dollars were included in the analysis.

We used the "REPEST" macro for Stata version 16 to compute weighted descriptive statistics for the pooled data and country-specific data respectively (research question one). The "REPEST" macro is a package of Stata code that creates macro programs that incorporate plausible values, sampling weights (SPFWT0), and replicate weights (SPFWT1-SPFWT80) for Stata (Avvisati & Keslair, 2014). We also used the REPEST macro to construct two sets of linear

regression models to the country-specific data: the first set treats AET PSTRE function of sex, age, income and PSTRE scores for a pooled sample of all countries and then for each individual country; the second one treats hourly wages as function of sex, age and PSTRE scores (research questions two and three). In the regression analysis, goodness of fit was assessed using the coefficient of determination (R-squared); the estimated coefficients, standard errors and significance were reported for all relevant parameters (a p-value of 0.05 used as criteria for statistical significance). The survey weights (sampling weights and replicate weights) were incorporated into all analyses to generate the inter-/nationally representative figures.

Results

We summarized the weighted descriptive statistics for the proportion of respondents in different age and sex groups in Table 1, as well as the weighted summary of PSTRE scores for different age, sex, and AET participation groups in in Figures 1 - 3. The age group percentages of respondents vary somewhat among the selected countries that featured some interesting characteristics of the employed population. For example, Greece had few younger (7.2% in the 24 or less group) and older (11.9% in the 55-65 group) respondents in the survey, while Australia had a more younger (16.8% in the 24 or less group) respondents. Both Japan and Finland appeared to have relatively smaller percentages of younger respondents (Japan: 9.9%, Finland: 10.0% in 24 or less group) and relatively larger percentages of the older respondents (Japan: 21.6%, Finland: 20.3% in 55-65 group). It is noteworthy that Estonia is the only country with fewer male respondents (48.8%) than female and Greece has the highest male proportion among the respondents (59.6%).

Table 1.

Weighted Descriptive Data for Employed Respondents in Selected Countries: Age Group and Sex (percent)

	U.S.	Australia	Chile	Estonia	Finland	Greece	Ireland	Japan
24 or less	15.1	16.8	13.7	11.3	10.0	7.2	11.0	9.9
25-34	22.8	23.4	25.6	24.9	22.0	22.9	28.9	20.0
35-44	21.3	23.1	21.9	24.8	22.7	31.4	26.0	26.0
45-54	23.3	22.0	22.6	22.6	25.1	26.6	20.6	22.5
55-65	17.6	14.8	16.3	16.5	20.3	11.9	13.4	21.6
Male	52.2	55.1	56.0	48.8	50.5	59.6	51.9	57.8
Female	47.8	44.9	44.0	51.2	49.5	40.4	48.1	42.2
Observations (unweighted)	4783	5603	3620	5393	3887	2463	3677	3881

To address the first research question (*What are the patterns of PSTRE scores by sex and age group?*), we compare the PSTRE scores by groups based sex and age in Figures 1 and 2, respectively. As shown in Figure 1, female respondents have relatively lower PSTRE scores on average in most countries, except for Australia and Greece; PSTRE scores of female respondents are also more consistent with smaller standard errors in most countries, except for Australia and Japan. The low PSTRE scoring countries, Chile and Greece, have much larger variations in the PSTRE scores for both gender groups. As shown in Figure 2, the 25-34 group has the highest average PSTRE scores in most countries, except for in Estonia and Greece. The low PSTRE scoring counties appeared to have the highest variability of PSTRE scores for almost all the age groups.

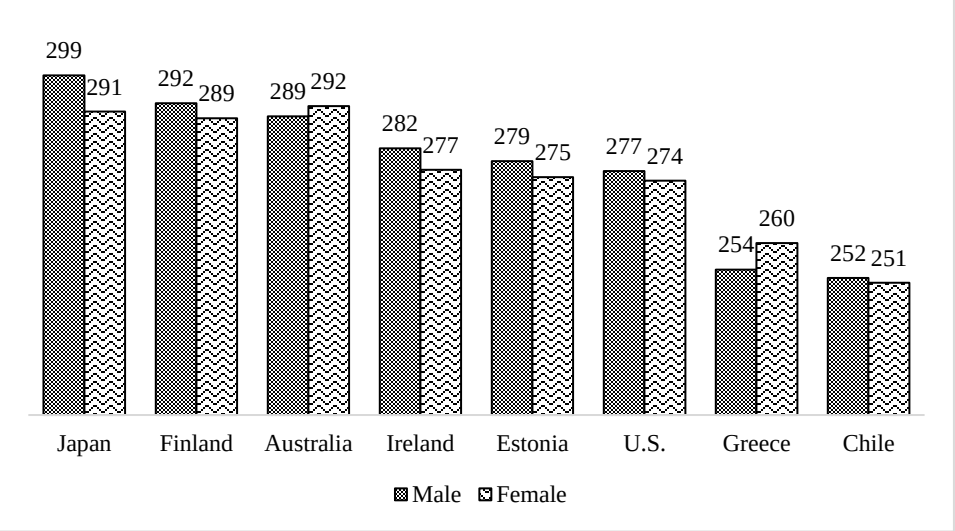
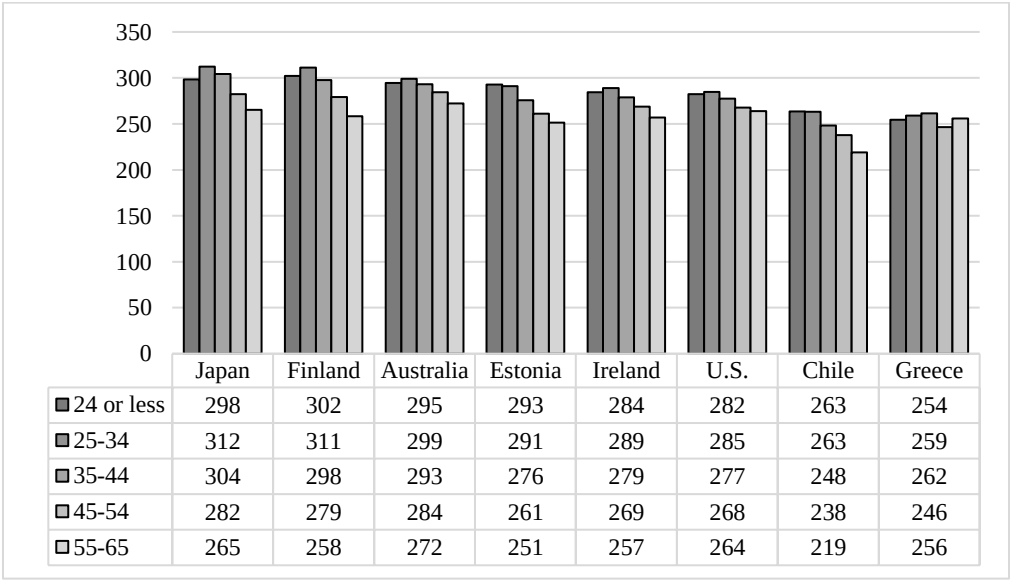


Figure 1. Weighted Average PRTRE Scores by Sex in Eight Selected Counties



	Japan	Finland	Australia	Estonia	Ireland	U.S.	Chile	Greece
24 or less	298	302	295	293	284	282	263	254
25-34	312	311	299	291	289	285	263	259
35-44	304	298	293	276	279	277	248	262
45-54	282	279	284	261	269	268	238	246
55-65	265	258	272	251	257	264	219	256

Figure 2. Weighted Average PSTRE Scores by Age Group in Eight Selected Countries

To address the second research question (*Is there a relationship between participation in AET and PSTRE scores and does it vary by age group and sex?*), we first compare weighted average PSTRE scores for those who participated in AET in the past 12 months to those who did not in Figure 3. In all countries, those who participated in AET had higher PSTRE scores. Subsequently, we fit weighted logistic regression models to the samples from each country, with AET participation as the response, PSTRE scores, age, sex, hourly wages and education as the predictors; the interactions of age/sex/education and PSTRE score/income were considered in addition to the main effects. Without considering PSTRE scores, we also compared AET participation by sex; those results are show in Figure 4. Finland had the highest overall AET participation rate and also the highest rate for both males and females while Greece had the lowest participation rates. Females in Finland and Estonia participated in AET at higher than males. Japan experience the widest AET participation gap between males and females (57% for males versus 44% for females).

The odds ratio (ratio of the probability of participating in AET and probability of not participating in AET) associated with each predictor/interaction in the model are summarized in Table 2 as well as the statistical significance. The PSTRE score was associated with the AET participation in all countries. However, the directions were inconsistent. That is, the PSTRE score was negatively associated with AET participation in the U.S. and Chile, whereas a positive association was observed in all other nations. With regards to the gender and age group differences in the PSTRE – AET participation relationships, males tend to benefit more from PSTRE scores than females. In other words, the effect of PSTRE on AET participation is greater among males than females. At the same time, the findings were not consistent across nations. In Australia and Greece, the effect of PSTRE on AET participation was greater among females than males. The findings of age group differences in the same context were also inconsistent.

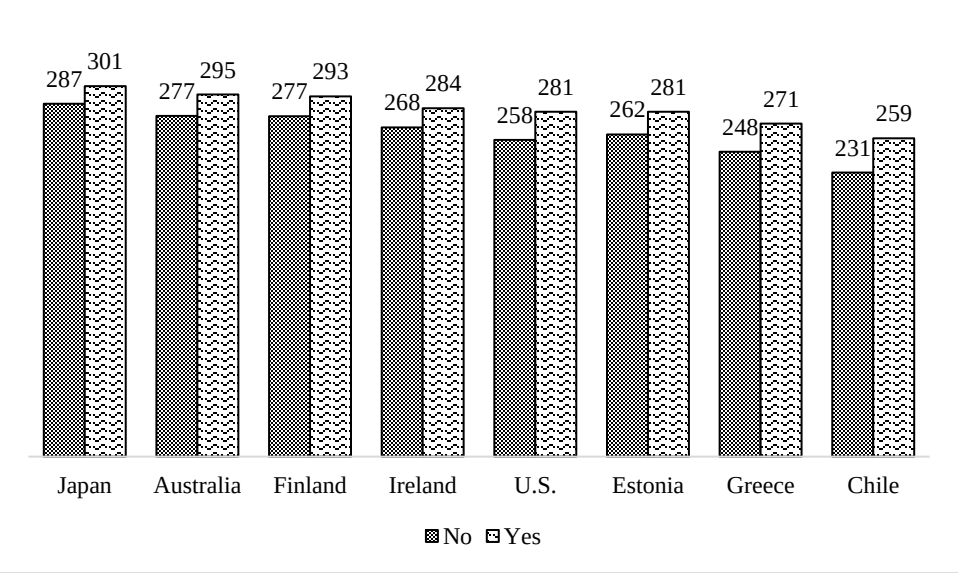


Figure 3. Weighted Average PSTRE Scores Comparing AET Participants and Non-Participants

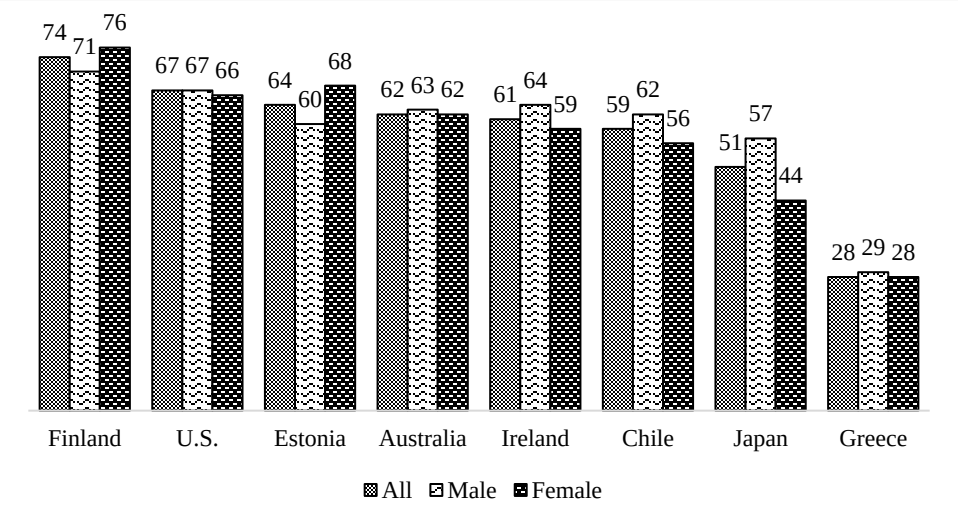


Figure 4. Weighted Average AET Participation by Sex (percent)

In the U.S., Estonia, Finland and Japan, the effects of PSTRE on AET participation were weaker in older age groups compared to the youngest age group. In other nations, the findings were opposite or mixed.

To address the third research question (*Are the PSTRE scores and AET participation associated with hourly wages, and do the association vary by age group and sex?*), we fit weighted linear regression models to the samples from each country respectively, with hourly wages as the response, PSTRE scores, AET participation, age, sex, and education level as the predictors; the interactions of age/sex/education and PSTRE score/AET

participation were considered in addition to the main effects. Results are presented in Table 3. Greater PSTRE scores were associated with higher hourly wages in the U.S. Australia and Estonia whereas no significant association was observed in other countries. Similarly, AET participation was associated with higher hourly wage only in the U.S., Chile, Ireland and Japan. With limited availability of data, females benefited from the PSTRE scores more than males in the U.S., Finland, Ireland and Japan. Also, in Estonia, females who participated in AET had higher hourly wages than their counterparts (e.g., males who participated in AET). It should be noted that females with similar PSTRE scores to males (controlling for age, AET participation, and education) generally had lower hourly wages than males except in Japan. Finally, the findings of age differences in the effect of PSTRE on hourly wages were inconsistent and inconclusive.

Table 2.

Estimated Effect of PSTRE Scores on Participation in Adult Education and Training

Outcome: AET participation	U.S.	Australia	Chile	Estonia	Finland	Greece	Ireland	Japan
	OR	OR	OR	OR	OR	OR	OR	OR
PSTRE	**0.9992**	**1.0028**	**0.9957**	**1.0155**	**1.0099**	**1.0088**	**1.0091**	**1.0011**
Lwage	**1.5140**	**0.4720**	**0.8095**	**0.9490**	**2.0149**	**1.3435**	**2.5249**	**1.5040**
Sex: Female	1.7430	1.2990	0.5431	3.5301	0.4041	0.1005	2.2435	2.0568
Age: 25-34	2.2619	0.0172	0.7309	0.8068	2.6225	0.6701	1.0064	4.2977
Age: 35-44	1.8805	0.0060	1.9893	2.9854	6.0157	0.5749	0.9074	5.1570
Age: 45-54	1.4339	0.0044	1.4725	3.3706	7.2556	1.1897	5.0865	3.4362
Age: 55-65	3.5301	0.0043	0.9467	0.5564	9.1612	0.0366	11.1805	5.1620
Education: Upper secondary	0.0563	0.5565	0.0940	1.8905	0.5892	21.6542	0.3202	0.0621
Education: Beyond upper secondary	0.1624	2.6703	0.4685	2.1255	2.2216	19.2462	3.7862	0.1193
Sex*PSTRE: Female*PSTRE	**0.9975**	**1.0006**	**0.9993**	**0.9935**	**0.9966**	**1.0018**	**0.9933**	**0.9948**
Age*PSTRE: 25-34*PSTRE	**0.9965**	**1.0073**	**1.0040**	**0.9968**	**0.9967**	**1.0044**	**1.0009**	**0.9972**
Age*PSTRE: 35-44*PSTRE	**0.9966**	**1.0045**	**0.9953**	**0.9936**	**0.9933**	**1.0045**	**1.0000**	**0.9955**
Age*PSTRE: 45-54*PSTRE	**0.9975**	**1.0069**	**1.0045**	**0.9888**	**0.9931**	**1.0004**	**0.9946**	**0.9979**
Age*PSTRE: 55-65*PSTRE	**0.9945**	**1.0024**	**1.0020**	**0.9918**	**0.9908**	**1.0106**	**0.9919**	**0.9948**
Education*PSTRE: Upper secondary*PSTRE	**1.0133**	**1.0001**	**1.0121**	**1.0021**	**1.0032**	**0.9910**	**1.0069**	**1.0098**
Education*PSTRE: Beyond upper secondary*PSTRE	**1.0123**	**0.9955**	**1.0049**	**1.0009**	**1.0005**	**0.9936**	**1.0000**	**1.0088**
Sex*lwage: Female*lwage	**1.0892**	**0.9196**	**1.4342**	**1.6707**	**2.2810**	**2.2041**	**1.3188**	**1.4292**
Age*lwage: 25-34*lwage		2.2648	**1.0554**	**1.6663**				
Age*lwage: 35-44*lwage		4.6476	**1.6386**	**1.3127**				
Age*lwage: 45-54*lwage		**4.2157**	**0.6184**	**2.2608**				
Age*lwage: 55-65*lwage		**6.2511**	**0.8636**	**3.4449**				
Education*lwage: Upper secondary*lwage		**1.3706**	**1.2683**	**0.6495**			0.8672	**1.2038**
Education*lwage: Beyond upper secondary*lwage		**1.6918**	**1.9540**	**1.0100**			**0.9335**	**1.3303**
Intercept	0.6992	5.6304	3.0443	0.0366	7.4927	0.1098	0.0155	0.2431

McFadden's Pseudo R-squared	0.0772	0.0983	0.1168	0.0934	0.0632	0.0946	0.0967	0.0806
Observations (unweighted)	2889	3396	1496	2802	2791	916	2039	2140

Notes: Significant relationships are shown in **bold** ($p < .05$). Due to space limitations, reference groups, and standard errors are omitted and are available upon request. For some countries where interactions were not significant, the interactions were excluded resulting in empty cells.

Summary and Implications for Practice

Problem solving skills and continued learning over the life course will continue to grow in importance with constant technological advances in global economies. This study offers insights into country level variations in PSTRE skills by gender and age and provides some understanding into preparedness for technological advances. In most countries, males had higher PSTRE scores than females, those with higher PSTRE scores were more likely to participate in AET, and PSTRE scores were generally lower as age increased. In several countries, those with higher wages were more likely to participate in AET, suggesting the need for continued skill upgrading over the life course and the need for increases in educational opportunities for low-skilled and income individuals throughout the life course. In addition, in most countries included in the study, females earned lower wages than males with similar PSTRE scores. Low PSTRE scores in Chile and Greece, which are economically less developed than other countries included in this study, could present additional challenges for them to advance technologically unless their populations are provided with increased educational opportunities.

Education, both initially and over the life course, is widely considered a mechanism for reducing equalities. Providing educational opportunities to those with low-income and skills has been a challenge for most countries, but is critical to reducing income disparities and to advance technologically. Countries typically consider funding for lifelong learning to be a shared responsibility among the individual, the employer, and the government with the government playing a more prominent role for low-skilled and unemployed workers (Cummins & Kunkel, 2015). It will continue to be important for policy makers and practitioners to identify strategies for providing these opportunities, both to reduce inequalities but also to have a workforce that can remain competitive.

Table 3.

Estimated Effect of PSTRE Scores on Log(wage)

Outcome: lwage	U.S. Coef	Australia Coef	Chile Coef	Estonia Coef	Finland Coef	Greece Coef	Ireland Coef	Japan Coef
PSTRE	**0.0024**	**0.0017**	-0.0028	**0.0025**	-0.0006	0.0007	0.0011	0.0012
Sex: Female	**-0.5331**	**-0.1803**	**-0.1846**	**-0.5116**	**-0.493**	**-0.0751**	**-0.6152**	**0.9408**
Age: 25-34	**0.2986**	**0.2032**	**-1.1984**	0.0646	-0.1009	0.0583	**0.2653**	**0.125**
Age: 35-44	**0.5334**	**0.2199**	**-1.2559**	**0.1632**	-0.3292	**0.3453**	**0.5277**	**0.3666**
Age: 45-54	**0.6292**	**0.2827**	-0.6045	-0.0419	-0.2961	**0.5251**	**0.6133**	**0.5428**
Age: 55-65	**0.695**	**0.2673**	0.1156	-0.1166	-0.1064	**0.7104**	**0.6392**	**0.6161**
AET participation: Yes	**0.0922**	-0.0927	**0.1352**	-0.1028	-0.0229	-0.2089	**0.1939**	**0.1592**
Education: Beyond upper secondary	**0.3042**	**0.168**	**0.5648**	**0.1927**	**0.2587**	**0.2012**	**0.2579**	**0.1255**
Sex*PSTRE: Female*PSTRE	**0.0012**				**0.001**		**0.002**	**0.0019**
Age*PSTRE: 25-34*PSTRE			**0.0054**		0.0007			
Age*PSTRE: 35-44*PSTRE			**0.0063**		**0.0018**			
Age*PSTRE: 45-54*PSTRE			0.004		**0.0019**			
Age*AET: 35-44*Yes		**0.193**		0.0803	**0.1187**			
Age*AET: 45-54*Yes		**0.174**		**0.2633**	**0.1506**			
Age*AET: 55-65*Yes		**0.2107**		**0.3584**	0.0818			
Education*AET: Upper secondary*Yes		0.0408				**0.3534**		
Education*AET: Beyond upper secondary*Yes		**0.1501**				**0.3533**		
Sex*AET: Female*Yes				**0.1377**				
Intercept	**1.6645**	**2.08**	**2.2996**	**1.5046**	**2.7147**	**1.6105**	**1.978**	**1.9882**
R-squared	0.3185	0.2574	0.2485	0.2224	0.327	0.2723	0.246	0.3243
Observations (unweighted)	2889	3396	1496	2802	2791	916	2039	2140

Notes: Significant relationships are shown in **bold** ($p < .05$), Due to space limitations, reference groups, standard errors and results which were not significant are omitted and are available upon request. For some countries where interactions were not significant, the interactions were excluded resulting in empty cells.

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