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Students' Access to Technology, Attitudes to ICT, and Their Performance on PISA 2015 Science in Ireland

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Abstract

This paper examines relationships between several aspects of ICT (availability, use and attitudes) and students' science achievement in PISA 2015. Results are examined for Ireland, comparison countries and on average across OECD countries. Compared to their peers in other OECD countries, students in Ireland reported lower availability of ICT at school, and were less likely to use ICT in school and at home for schoolwork but also showed greater interest in ICT and higher perceived ICT autonomy and competence. Perceived ICT autonomy and competence had significant positive correlations with science performance. Hierarchical linear models indicated a negative relationship between science performance and general ICT use at school level, and between performance and availability of ICT at student level. The findings are examined with reference to lower-than-expected performance in Ireland on PISA 2015 science. The need to further embed digital technologies into teaching, learning and assessment is considered.

Keywords: ICT access use and attitudes, PISA science, ICT and science achievement

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Information and communication technology (ICT[1]) is a key part of modern life. Technology has been evolving since the introduction of the personal computer in the 1970s, with handheld and wearable technologies now driving dependence on information and knowledge in digital formats. Many aspects of everyday life are

1 The term 'ICT' used throughout the paper is consistent with terminology used by the OECD in reporting findings relating to digital technologies for PISA 2015.

mediated through digital technology, including phones, satellite navigation systems, watches, laptops and computers, making it essential for young people to become digitally literate. Therefore, it is important to include digital literacy in the range of skills and knowledge students need to acquire, to enable them to reach their potential.

The shift towards digital technology is apparent in the wider context of international assessments, with PISA, TIMSS and PIRLS[2] all transitioning to computer-based assessment in recent years. At a national level, standardised assessments in reading and mathematics, at primary and post-primary levels, are available to complete online (www.tests.erc.ie). The importance of digital skills is also underlined in the Department of Education and Skills' *Digital Strategy for Schools 2015-2020* (DES, 2015). The strategy, which covers primary and post-primary levels, builds on research in the area including the ICT census (Cosgrove et al., 2014) and a consultation paper on integrating ICT into teaching and learning (Butler et al., 2013). The subsequent *Digital Learning Framework* (DES, 2017) provides structure for the embedding of digital technologies into teaching, learning and assessment in schools in Ireland.

While Ireland has been singled out as a top-performing country in digital reading skills among countries that participated in the digital version of the Progress in International Reading Literacy Study (ePIRLS) in 2016 (Fau & Moreau, 2018; Eivers et al., 2017), performance in other digitally-based studies, administered on computer, has been mixed. In general, consistently higher results have been reported for reading literacy over other domains (Central Statistics Office [CSO], 2013; Perkins et al., 2013; Perkins & Shiel, 2014; Shiel et al., 2016). For example, in PISA 2015, while Ireland's mathematics, science and reading literacy mean scores were significantly above the corresponding OECD averages, Ireland stood out as one of the top performing OECD countries in reading literacy. In contrast, in PIAAC 2012[3], the mean literacy score of adults in Ireland was not significantly different from the international average; Ireland was below the international average in numeracy, and more Irish adults performed below Level 1 in problem-solving in technology-rich environments compared to the international average (CSO, 2013).

In this paper, the relationships between several aspects of ICT (availability, use and attitudes) and students' science achievement in PISA 2015 are explored. Results for

2 PISA, the Programme for International Study Assessment, is sponsored by the Paris-based Organisation for Economic Co-operation and Development (OECD) and has been implemented on a triennial basis since 2000, with tests in Reading Literacy, Mathematics and Science administered to 15-year-olds, with 72 countries taking part in the 2015 round; TIMSS, the Trends in International Mathematics and Science Study, is sponsored by the International Association for the Evaluation of Educational Achievement (IEA) in Amsterdam, and has been administered at Grades 4 and 8 every four years since 1995, with 54 countries taking part in 2015; and PIRLS (the Progress in International Reading Literacy Study), also sponsored by the IEA, has been administered to students in Grade 4 every five years since 2001, with 50 countries taking part in 2016.

3 PIAAC, the OECD's Programme for the International Assessment of Adult Competencies, was administered to nationally representative samples of adults (aged 16 to 65 years) in 24 countries including Ireland in 2013. Adults selected to participate had the option of completing the assessment on paper or on computer. In Ireland, 17% of adults opted to complete the assessment on paper (even through many of them had prior experience with computers), compared with 9% internationally. The second cycle of PIAAC takes place during 2021-2022 in which Ireland is participating.

Ireland, averages across OECD countries, and comparisons with selected countries (Australia, Germany, Korea and the Netherlands[4]), are examined to establish which ICT variables are most strongly associated with performance in PISA 2015 science.

Review of the Literature

The relevant literature indicates mixed findings from PISA and non-PISA publications pertinent to ICT and achievement. Issues emerging as lessons from previous PISA cycles, and more generally from the greater integration of technology in teaching, learning and assessment include rapid but unequal expansion of access to ICTs, a fast-changing ICT environment, and unexpected relationships between students' ICT use and their cognitive outcomes (Lorenceau et al., 2019).

As difficulties related to access to ICT (known as the first digital divide) lessen in developed countries, the ability to use and interact with ICT effectively is now regarded as having a greater significance (Azzolini & Schizzerotto, 2017; DiMaggio & Hargittai, 2001). In highlighting 'unequal expansion', Lorenceau at al. (2019) point out that while most students in most countries have access to 'generic' ICT resources, access is not universal across developing countries, as advantaged students spend more time online than their disadvantaged peers. Ireland was identified as one of the countries with high growth in Internet use over the period 2012-2015 (OECD, 2018), though most of the growth occurred at home rather than at school. In developed countries with universal access (like Ireland), ICT use is increasing and diversifying, with disadvantaged students spending more time online than their advantaged peers, especially outside of school (Lorenceau et al., 2019). However, time spent online may not be directly related to effective use or embedding of technology for learning. In an analysis of the relationship between ICT use at school and students' cognitive outcomes on digital reading and print reading scores (PISA 2012), Lorenceau et al. (2019) found that students with the highest performance in both modes used ICT in school less than the average OECD student. In PISA 2015, the average change in science mean scores[5] associated with a one-hour increase in time spent on the Internet outside of school during weekdays was negative in Ireland (-6 score points) and on average across OECD countries (-4), both statistically significant, raising questions about optimal levels (and perhaps kinds) of Internet use (OECD, 2018).

Use of ICT and Academic Achievement

Recent research, utilising data from international large-scale assessments such as PISA and TIMSS, has provided conflicting findings regarding the relationship between ICT

4 Australia, Germany and the Netherlands were selected because they performed at about the same level as Ireland in PISA 2012 science and, like Ireland, their performance on science declined significantly between PISA 2012 and 2015. Korea also experienced a large decline in science performance in the same period.

5 Given the standard deviation of around 100 on the PISA achievement scales, a score difference of 25 points or more would be considered substantial.

use and academic achievement. Some studies have identified positive associations, with higher use of ICT for educational purposes indicative of higher performance on PISA (although mostly on paper-based tests) (e.g., Kubiatko & Vlckova, 2010; Yang et al., 2019). Other studies have reported a negative association between ICT use and academic performance (Zhang & Liu, 2016; Güzeller & Ayça, 2014; Ziya et al., 2010). Findings from the OECD (2015) also highlight a negative association, with computers more likely to be used by lower-achieving students. Zhang and Liu (2016) reference Karpati's (2004) view that educational software on computers is often used to assist students who are falling behind. Still other studies found no significant relationship between performance and ICT use or reported mixed results (Petko et al., 2017; Skryabin et al., 2015). In considering this variation in findings, Orben and Przybylski (2019) note that caution should be exercised in investigating effects in large-scale data sets, due to the limitations of such data, which are typically cross-sectional, and may give rise to unwarranted conclusions.

Two recent PISA-related publications underline the issue of mixed results across one or more cycles of a study. Bulut and Cutumisu (2017) examined PISA 2012 data for Turkey and Finland and found a significant negative relationship between ICT use at school and performance on the mathematics and science assessments. A positive association between using ICT at home for school-related tasks and performance on these assessments was identified for students in Turkey (where ICT devices were less prevalent) but no effect was found for students in Finland (where ICT was widely available). On examination of data from all participating countries across five cycles of PISA (from 2000 to 2012), Zhang and Liu (2016) identified negative associations between ICT use and mathematics and science achievement in three cycles (2000, 2003, 2006). Looking at Internet use for education purposes, a significant negative relationship was observed in 2009 between Internet use at home and at school and performance on mathematics and science. In 2012, however, a negative association was found for Internet use at school only, with non-significant positive and negative relationships, respectively, between maths and science outcomes and Internet use at home (Zhang & Liu, 2016). Overall, taking the literature from PISA and other studies into account, there is ambiguity on how technology use and performance, as measured by large-scale assessments, are related.

Gender Differences in Attitudes to ICT

A number of studies highlight that ICT attitudes and skills differ by gender (e.g., Tømte & Hatlevik, 2011). Research from PISA 2012 found that female students evaluate their abilities in ICT less positively than males (OECD, 2015; Meggiolaro, 2018). Though indicating less positive attitudes to ICT, female self-reported ICT competencies are at a similar or higher level than that of their male counterparts (Aesaert et al., 2017; Hatlevik et al., 2018). The latter finding differs from a previous one which showed that female students were less knowledgeable about ICT – see

Janssen Reinen and Plomp's (1997) study based on 70,622 students across primary and secondary schools in 20 countries.

Risk of Self-Report Bias

Aesaert et al. (2017), in their research involving 58 primary schools in Belgium, note that reporting bias may be a factor in investigating the relationship between attitudes, self-beliefs and achievement. How students report on their attitudes and self-beliefs with respect to ICT such as their competency and autonomy in implementing ICT skills can be over- and under-estimated, meaning that reported levels may not reflect actual ICT skills and performance outcomes of students in ICT-related tasks. In their analysis of Israeli junior-high school students (N = 280), Porat et al. (2018) noted how younger generations evaluate themselves as having higher competency and skills in ICT than may be reflected in computer-based assessments. A disparity between attitudes and performance may come to light more acutely in a study such as PISA, with attitudinal variables and the outcome measures (achievement) both gathered during a single administration of a computer-based assessment.

PISA 2015

PISA aims to investigate how well 15-year-old students master key subjects or domains (reading literacy, mathematics and science) in order to be prepared for real-life situations in the adult world. It was administered entirely on computer for the first time in 2015 in about 50 countries, following on from previous paper-based cycles that included add-on computer-based assessments of reading, mathematics, science and problem-solving. In the 2015 cycle, science was the main domain assessed and it provides the data for the analyses presented in this paper.

The overall performance of students in science in Ireland dropped by 19 points between PISA 2012 and PISA 2015, compared with a drop of eight points on average across OECD countries (Shiel et al., 2016). Female students in Ireland performed less well when compared to their male counterparts, with a statistically significant 10.5 score-point difference, higher than the average gender difference across the OECD of 3.5 score points. Apart from any changes in student or school contextual measures, this significant drop in performance may be the result of factors such as changes in the design and scaling of PISA, the updating of the science framework for PISA 2015, the introduction of new item types (e.g., interactive simulations of experiments), and/or the transition to the computer-based testing platform. It is also worth noting that students in Ireland may be relatively inexperienced in taking tests on computer compared to students in other countries, as state examinations are mainly paper based.

This paper focuses on the implications of transitioning from paper to computer assessment in PISA 2015. It draws on information gathered in the PISA 2015 student questionnaire relating to students' attitudes towards digital technologies and competences in using digital devices inside and outside of school. To examine levels of availability and frequency of use of digital devices in addition to students' familiarity with digital technologies, their perceived ability to carry out computer tasks and their attitudes towards computers, data were drawn from the PISA 2015 ICT Familiarity Questionnaire (also referred to as ICT Questionnaire), which was administered in conjunction with the PISA tests (OECD, 2016).

Methodology

Data

In Ireland, 5,741 students (roughly equal numbers of male and female students) from 167 schools took part in PISA 2015. Participants were aged between 15 years and 3 months and 16 years and 2 months and were distributed across four grade levels – Second year (1.9%), Third year (60.5%), Transition year (26.7%), and Fifth year (10.9%). All OECD countries except Canada, Norway, Turkey and the United States administered the ICT questionnaire. Unlike in previous cycles of PISA, the ICT Questionnaire administered in 2015 focused on general aspects of ICT and was not domain-specific (that is, questions did not relate specifically to science and ICT).

The ICT Questionnaire (ICTQ) consisted of 16 items focusing on how students currently use digital devices at home and at school, and their attitudes towards ICT (see Table 1). Six derived indices, developed by the OECD, were identified from items on students' access to ICT, type and frequency of ICT use, and self-reported interest, competency and autonomy in ICT. The indices summarised students' responses to related items, with higher scores indicating a higher or more strongly-expressed attitude/self-belief. Table 1 outlines the PISA-created indices used in the analysis and provides some item examples.

TABLE 1

List of ICT-related Indices Derived from the PISA 2015 ICT Questionnaire (ICTQ)

Derived Index	Item Example	Frequency
Availability of ICT in school*	Available devices: e.g., desktop computer, Internet connection	Yes & I use, Yes, but I don't use, No
ICT use for schoolwork outside of school*	Using email at school to communicate with other student about schoolwork	Never or hardly ever, Once or twice a month, Once or twice a week, Almost every day, Every day
Use of ICT at school in general*	Chat online at school	As previous
Interest in ICT	I forget about time when I'm using digital devices	Strongly disagree, Disagree, Agree, Strongly agree
Students' perceived ICT competence	I feel comfortable using my digital devices at home	As previous
Students' perceived autonomy	I use digital devices in the way I want to use them	As previous

* The responses of students within a school for these variables were averaged to generate school-level data.

Analysis

To explore associations between ICT variables and science performance using 2015 data, school-related indices (as reported by the students, availability and use of ICT in schools, use for schoolwork outside of school) were aggregated to school level and then examined with reference to school type[6] and DEIS[7] status. Non-DEIS schools and vocational schools were selected as the reference groups. Mean scores on student perceived autonomy, competency and interest in ICT were examined in relation to science performance through correlational analyses[8], with comparisons by gender and economic, cultural and social status (ESCS[9]). Values on the selected indices are compared for each ESCS quartile. Females and the highest index and ESCS quartiles (Q4) were selected as the reference groups at the student level. Comparisons with OECD averages and specific OECD countries are also included for student- and school-level indices.

6 School type consists of the following categories: boys' secondary, girls' secondary, mixed schools, community/comprehensive, and vocational schools. In this paper, we use the term 'vocational' to refer to schools under the management of the Education and Training Boards (ETBs).

7 DEIS (Delivering equality of opportunity in schools), a programme designed to give tailored support to schools with high concentrations of disadvantage, is a core part of addressing social inclusion in education policy in Ireland (https://www.education.ie/en/Publications/Policy-Reports/DEIS-Plan-2017.pdf).

8 Correlation coefficients are described as follows: A score below .10 is a weak correlation, between 0.11 and 0.25 is a weak to moderate correlation, between 0.26 to 0.40 is a moderate correlation, between 0.41 and 0.55 is a moderate to strong correlation and a score of 0.56 or over is a strong correlation.

9 The OECD's index of socioeconomic status.

Hierarchical linear modelling (HLM) was used to model the relationships between student-level and aggregated school-level ICT variables and science performance. Variables selected for inclusion in the model were those that were significantly associated with science performance in the first stage of analysis. Residual variances in each model were compared with those of the null model so that the proportions of between- and within-school variance accounted for by each model could be estimated.

Results

On the composite index of availability of ICT at school[10], Ireland had a significantly lower mean score (5.91) than the OECD average (6.08), with this difference of around 0.17 equating to a little under one-tenth of a standard deviation (Table 2). Availability of ICT at school was significantly higher than in Korea (5.62) but significantly lower than in Australia (7.60) and the Netherlands (6.96). Students in Ireland were also significantly less likely to use ICT at school in general (-0.38, two-fifths of a standard deviation below the OECD average of 0.0) and outside of school for schoolwork (-0.42, again two-fifths of a standard deviation below the OECD average) than students on average across OECD countries (mean of 0 on both scales) (Table 2). As in Ireland, students in Germany (-0.42) and Korea (-0.95) reported below-average use of ICT in schools, while students in the Netherlands (0.44) and Australia (0.56) reported above average use (Appendix Table A3). Similar to their peers in Ireland, students in Germany (-0.38) and Korea (-0.34) reported levels of ICT use outside of school that were below the corresponding OECD average, while those in Australia (0.16) and the Netherlands (0.17) reported above average use.

Differences between DEIS and non-DEIS schools are also shown in Table 2 (with schools in the DEIS programme serving educationally disadvantaged communities). ICT was significantly more widely available to students in DEIS schools than in non-DEIS schools (with a difference of around one-quarter of a standard deviation). No significant differences were found between DEIS and non-DEIS schools for use of ICT at school in general or for ICT use outside school for schoolwork.

10 Not all indices are scaled in the same way; for example, availability of ICT at school has an OECD average of 6.08 and a standard deviation of 2, while most others (e.g., interest in ICT) have an OECD average of around 0, and a standard deviation of 1.

TABLE 2

School-focused ICT Indices in PISA 2015, Ireland and OECD Average

Index		Mean Score	Difference -DEIS & Non-DEIS Schools	Mean by School Type	Correl. with SCI	Difference in Science Performance by ICT Index Quartiles
Availability of ICT in school	IREL	**5.91**	**DEIS Schools 6.26** Non-DEIS Schools 5.85 (R)	**Girls' Sec 5.55** **Boys' Sec 5.65** Mixed Sec 5.85 Comm/Comp 6.04 Vocat 6.35 (R)	**-0.12**	**Q1 513.9** **Q2 515.6** **Q3 513.4** Q4 485.7 (R)
	OECD Avg	6.08	N/A	N/A	**-0.08**	**Q1 483.1** **Q2 516.3** **Q3 514.0** Q4 475.7 (R)
Use of ICT at school in general	IREL	**-0.38**	DEIS Schools -0.30 Non-DEIS Schools -0.40 (R)	**Girls' Sec -0.48** **Boys' Sec -0.45** Mixed Sec -0.42 **Comm/Comp -0.38** Vocat -0.23 (R)	**-0.11**	**Q1 505.9** **Q2 510.2** **Q3 513.4** Q4 488.6 (R)
	OECD Avg	0.01	N/A	N/A	**-0.12**	**Q1 491.1** **Q2 511.2** **Q3 512.0** Q4 476.2 (R)
Use of ICT outside of school, for schoolwork	IREL	**-0.42**	DEIS Schools -0.46 Non-DEIS Schools -0.41 (R)	Girls' Sec -0.40 **Boys' Sec -0.49** Mixed Sec -0.47 Comm/Comp -0.42 Vocat -0.34 (R)	**-0.05**	Q1 500.2 **Q2 519.6** **Q3 512.7** Q4 485.5 (R)
	OECD Avg	0.00	N/A	N/A	**-0.08**	**Q1 489.5** **Q2 520.5** **Q3 511.7** Q4 471.2 (R)

See Appendix Table A1 for standard errors associated with mean scores.

Students in vocational[11] schools had the highest scores on all three ICT indices, compared with other school types (Table 2). Students in both boys' and girls' secondary schools reported significantly lower ICT availability than students in vocational schools. Along with their peers in community/ comprehensive schools, students in girls' and boys' secondary schools reported significantly lower use of ICT at school than students in vocational schools. Use of ICT outside of school for schoolwork was low across all school types, and significantly so for students in boys' secondary schools, compared with students in vocational schools.

Correlations between science performance and availability of ICT at school, use of ICT at school, and use of ICT outside school for schoolwork were also examined (Table 2). A weak but significant negative correlation[12] was observed between science performance and availability of ICT at school, r = -.12, p<.01, indicating that performance tended to be higher in schools with lower levels of ICT availability. A significant negative correlation was also evident between science performance and use of ICT at school, suggesting that performance tended to be higher in schools with lower levels of ICT use. This relationship was in the weak to moderate range, r = -.11, p<.01. In addition, use of ICT outside school for schoolwork was negatively correlated with science scores. This correlation was weak but significant, r = -.05, p<.01.

In comparison to international findings, Ireland (along with the Netherlands, r = -0.13) had one of the weakest correlations between ICT availability in school and science performance. Regarding the use of ICT in school, Ireland's negative correlation was similar to those found for a number of comparison countries (Germany, r = -0.12; Korea, r = -0.11; and the Netherlands, r = -0.06) (Appendix Table A5). Germany was the only other comparison country with a negative correlation between science performance and the use of ICT for schoolwork outside of school (Germany r = -0.07). Although the OECD average correlation was lower than in Ireland on this index, the remaining comparison countries had positive correlations (Table A5).

To further investigate ICT use (at school, outside school for schoolwork) and science performance in Ireland, associations were examined between quartiles of the school-focused ICT indices and science mean scores, with the fourth quartile (highest) of each index identified as a reference group (Table 2, last column). Students in the highest quartile of ICT use at school (Q4) scored significantly lower on science (mean = 488.6) than students in all other quartiles. Across indices, science scores generally increased or stayed the same from Q1 to Q2 or Q3 before reducing significantly for Q4. For ICT use outside school for schoolwork, science performance was lowest for Q4 (most ICT use) followed by Q1 (least ICT use). These patterns are broadly consistent with the

11 Vocational schools, formerly administered by Vocational Education Committees, are now managed by Education and Training Boards (ETBs).

12 Correlation coefficients are described as follows: A score below .10 is a weak correlation, between 0.11 and 0.25 is a weak to moderate correlation, between 0.26 and 0.40 is a moderate correlation, between 0.41 and 0.55 is a moderate to strong correlation and a score of 0.56 or over is a strong correlation.

OECD average scores across quartiles (also reported in Table 2).

Student-level Attitudinal Variables

Students in Ireland reported higher than average interest in ICT, with a mean score of 0.32 which is about three-tenths of a standard deviation higher than the OECD average (0.01), and also significantly higher than in Australia (0.18), the Netherlands (0.05), Germany (0.05) and particularly compared with Korea (-0.37) (Table 3). In Ireland, no significant gender difference was observed on interest in ICT, with a mean score of .34 for females and .30 for males. In contrast, on average across OECD countries, males (.04) reported slightly but significantly higher interest in ICT than females (-.02). Unlike Ireland, all comparison countries reported levels of interest among males as equal to, or higher than, those among females (Appendix Table A4). In comparison with the OECD average (0.01), students in Ireland (0.11) had a significantly higher level of perceived ICT autonomy. In Ireland and on average across OECD countries, males displayed significantly greater perceived autonomy than females; this pattern is also found across comparison countries (Appendix Table A4).

Similar to interest in ICT and perceived autonomy, a significantly higher level of perceived ICT competence was reported by students in Ireland (0.21) than on average across OECD countries (mean = .01) (Table 3). Again, in Ireland, and on average across OECD countries, male students were significantly more likely than female students to perceive themselves as being competent in relation to ICT. However, across this set of ICT indices, female students in Ireland had higher scores than females in comparison countries (Appendix Table A4).

In Ireland, a significant positive correlation was observed between perceived autonomy related to ICT use and performance on science, $r = 0.18$, $p<.01$. A significant positive correlation was also evident for perceived ICT competence and science scores, $r = 0.12$, $p<.01$. Both of these relationships are in the weak to moderate range. Interest in ICT was not significantly correlated with science performance ($r = .06$, $p.>.05$).

Significant though small differences were observed across the ESCS quartiles on interest in ICT, while for the two other indices (perceived autonomy and perceived competence) significant differences were present only between Q1 and Q4 (reference group), whereby students in Q1 had significantly higher scores than those in Q4 on both of these indices. On average across OECD countries, significant differences were found across ESCS quartiles (except for Q3 in interest in ICT).

When examining the science performance scores of students in the top and bottom quartiles on attitudes to ICT, it can be seen that there are large differences on the indices of interest in ICT and perceived autonomy in ICT. Notably, there is a 44-point difference (almost one-half of an OECD average standard deviation) in science performance favouring students who view themselves as the most autonomous in using ICT, compared with those who see themselves as least autonomous, compared with a 38-point difference across the OECD on average (Table 3).

TABLE 3

Student-focused ICT Indices in PISA 2015, Ireland and OECD Average

Index		Mean Score	Gender Difference in Mean Scores	Correl. with SCI	Mean Score by ESCS Quartiles	Difference in Science Performance by ICT Index Quartiles
Interest in ICT	IREL	**0.32**	Male Students 0.30 Female Students 0.34 (R)	0.03	**Q1 0.28** **Q2 0.32** **Q3 0.33** Q4 0.35 (R)	**Q1 474.0** **Q2 493.9** **Q3 513.6** Q4 511.3 (R)
	OECD Avg	**0.01**	**Male Students 0.04** Female Students -0.02 (R)	**0.18**	**Q1 -0.08** **Q2 0.00** Q3 0.03 Q4 0.06 (R)	**Q1 480.1** **Q2 508.8** Q3 503.8 Q4 505.0 (R)
Perceived ICT Autonomy	IREL	**0.11**	**Male Students 0.30** Female Students -0.09 (R)	**0.18**	**Q1 0.01** Q2 0.09 Q3 0.12 Q4 0.21 (R)	**Q1 483.3** **Q2 506.6** **Q3 503.8** Q4 527.3 (R)
	OECD Avg	**0.01**	**Male Students (0.25)** Female Students -0.24 (R)	**0.14**	**Q1 -0.14** **Q2 -0.02** **Q3 0.02** Q4 0.12 (R)	**Q1 483.4** **Q2 502.1** **Q3 498.1** Q4 521.3 (R)

TABLE 3 *(contd.)*

Student-focused ICT Indices in PISA 2015, Ireland and OECD Average

Index		Mean Score	Gender Difference in Mean Scores	Correl. with SCI	Mean Score by ESCS Quartiles	Difference in Science Performance by ICT Index Quartiles
Perceived ICT Competence	IREL	**0.21**	**Male Students 0.31** Female Students 0.11 (R)	**0.12**	**Q1 0.13** Q2 0.23 Q3 0.23 Q4 0.27 (R)	**Q1 495.2** **Q2 492.3** Q3 516.4 Q4 516.5 (R)
	OECD Avg	**0.01**	**Male Students 0.18** Female Students 0.16 (R)	**0.10**	**Q1 -0.13** **Q2 -0.02** **Q3 0.03** Q4 0.11 (R)	**Q1 486.8** **Q2 499.8** **Q3 497.8** Q4 514.1 (R)

Note. Significant differences are shown in **bold**. See Appendix Table A2 for associated standard errors.

Q1 to Q4: Lowest to highest ranked quartile. Significant differences in mean science performance are in comparison with Q4 (R). Significant differences in gender are in comparison with female students (R).

Hierarchical Linear Model Outcomes

In Ireland, 14.1% of the total variance in students' science performance is due to differences between schools. This indicates that most of the differences in science scores lie between students rather than between schools.

As noted earlier, the indices based on student reports' of availability of and use of ICT at school in general were aggregated to the school level for the purpose of the hierarchical linear model. Table 4 shows the results of three models that examine the multivariate relationships between ICT related variables on science performance in PISA 2015. Three separate models were computed in order to describe the separate and joint effects of socioeconomic and structural variables and of ICT variables. Model one examined only socioeconomic and structural variables (gender, ESCS status, school type) with science performance. Model two examined effects of ICT variables only on science performance. Model three combined socioeconomic and structural variables with ICT variables to examine their joint effect on science performance.

Variance estimates from models one and two indicate that each set of variables, when examined individually, accounts for variance at both school and student level. Specifically, the bottom part of Table 4 shows that Model 1 explains 14.7% of the total variation in science achievement (7.1% within schools and 61.1% between schools); Model 2 accounts for 9.8% of total variation in science achievement, and Model 3 explains 18.3% of total variation. It should be noted that the overall explanatory power of the models is quite low.

Notably, however, Model 3 explains an additional 3.6% of the total variation in science achievement, i.e. an additional 2.8% of within-school variation, and an additional 9.8% of between-school variation).

An examination of the parameter estimates across the three models indicates that:

- School and student ESCS and student gender are related to science achievement independently of the ICT measures, since the parameter estimates for these measures remain almost the same in Models 1 and 3.
- Differences across school types are smaller and non-significant in Model 3 compared with Model 1, indicating that differences in science achievement across school types are accounted for by differences in (aggregate) ICT use at school.
- At the student level, perceived ICT competence and availability of ICT in school are weakly and negatively associated with science achievement, both with and without adjustments for ESCS, student gender and school type, indicating that these effects are occurring independently (over and above) the Model 1 variables.

TABLE 4

Model of ICT Attitudes, Use and Science Performance in PISA 2015

	Model 1			*Model 2*			*Model 3*		
	Parameter	*SE*	*p.*	*Parameter*	*SE*	*p.*	*Parameter*	*SE*	*p.*
School-Level Variables									
School ESCS (Aggregated)	**0.72**	0.05	0.00	~	~	~	**0.76**	0.05	0.00
School Type (R = Vocational)			*0.00						*0.20
Girls' Secondary	**0.57**	0.14		~	~	~	0.26	0.17	
Boys' Secondary	**0.67**	0.16		~	~	~	0.35	0.18	
Community/ Comprehensive	**0.33**	0.16		~	~	~	0.12	0.16	
Mixed	**0.25**	0.24		~	~	~	0.03	0.22	
Availability of ICT in school (Aggregated)	~	~	~	**-0.21**	0.10	0.04	-0.03	0.06	0.58
Use of ICT at school in general (Aggregated)	~	~	~	**-0.24**	0.12	0.04	**-0.30**	0.08	0.00
Student-Level Variables									
Gender (R = Female)	**0.12**	0.04	0.00	~	~	~	**0.14**	0.04	0.00
Students' ESCS Status	**0.27**	0.01	0.00	~	~	~	**0.27**	0.01	0.00
Students' perceived ICT competence	~	~	~	**-0.09**	0.04	0.01	**-0.07**	0.03	0.04
Students' perceived ICT Autonomy	~	~	~	-0.02	0.03	0.47	-0.03	0.03	0.33
Availability of ICT in school	~	~	~	**-0.12**	0.01	0.00	**-0.12**	0.01	0.00
Use of ICT at school in general	~	~	~	0.03	0.03	0.31	0.01	0.03	0.65
% of Variance Explained									
Within	7.1			2.2			9.8		
Between	61.1			56.1			70.0		
Total	14.7			9.8			18.3		

* Overall significance value for school type, in each model. Note. P values associated with significant item parameters are shown in **bold**.

Conclusion

Key findings from the paper indicate that students in Ireland reported lower availability of ICT at school than on average across OECD countries, and were less likely to use ICT in school and at home for schoolwork. Students in Ireland showed a greater interest in ICT and greater perceived autonomy and perceived competence in using ICT, than on average across OECD countries. In Ireland, availability of ICT was significantly higher in DEIS schools than non-DEIS schools, and in vocational schools compared with all other school types.

Significant though weak negative correlations were observed between science performance and all three school-level ICT variables, in Ireland and on average across OECD countries, with greater ICT availability and use associated with lower academic performance. Notably, students who ranked in the highest quartile of ICT availability and the highest quartile of ICT use at school scored significantly lower on PISA science than those in all other quartiles.

The results of the hierarchical linear model are of significance since they confirm that the associations between both school-level and student-level ICT indicators are occurring largely independently of ESCS, gender and school type, and are also consistent with the bivariate analyses presented in this paper. In the model, use of ICT at school had a weak negative relationship with science performance, independent of socioeconomic and sectors variables in the model.

It is worth noting that, over time, the concept of digital literacy or the building of 'digital skills' has evolved, and is a wide-ranging concept (Fau & Moreau, 2018). This in itself can prove challenging when developing ICT questions to track the breadth and diversity of ICT use, practices and dispositions across cycles of a national or international study. Several of the derived indices administered to students in 2015 were not implemented in 2018 and are not set for administration in PISA 2021, due to the fast-changing digital and technological environment. As Lorenceau et al. (2019, p.16) point out, 'the rapid expansion and diversity of digital technologies challenges the ICT familiarity questionnaire in different ways'. In preparation for PISA 2021, a PISA expert group advised the OECD on the development of a new ICT framework and updated questionnaire, with the ICT questions to be administered in the 2021 cycle largely different from those in the 2015 questionnaire. A limitation of the 2015 ICT questionnaire (and of these analyses) is the focus on students' general attitudes towards and use of ICT, which were not educationally contextualised in all instances, possibly resulting in a somewhat limited investigation of the range of motivations and intentions behind ICT use. This may in part explain the negative associations between ICT indices and science achievement reported in this paper.

The results outlined are in line with the OECD's (2015) report, *Students, Computers and Learning: Making the Connection,* which drew on PISA 2012 data and other literature to confirm negative associations between ICT use and performance (Bulut & Cutumisu, 2017; Zhang & Liu, 2016) and support Lorenceau et al's (2019) assertion that the potential positive impact of ICT use is dependent on how technology is used, in different places and for different purposes, but particularly for learning.

The bivariate findings related to *attitudes* to ICT uphold those of both Lee and Wu (2012) and Senkbeil (2018) who reported a positive relationship between students' perceived attitudes to ICT and academic achievement. The findings also support the assertion that attitudes towards ICT may have consequences for students' educational outcomes (Scherer et al., 2017). As highlighted, there was a 44-point difference in science performance between those who reported the lowest and highest perceived autonomy in ICT. This significant difference in scores is consistent with findings by Moos and Azevedo (2009), who emphasised the effects that both positive and negative attitudes to ICT can have on student performance. Their paper highlighted that behavioural and psychological factors are positively related to computer self-efficacy, and that self-regulating processes facilitate learning in computer-based learning environments. They also related findings to the importance of mastery experiences and argued that easy successes may undermine the development of self-efficacy with unrealistic expectations of future results (Bandura, 1994). This implies that students may need to be sufficiently challenged to acquire core digital skills and understand their own strengths and weaknesses. The fact that the hierarchical linear model revealed a weak *negative* or non-significant relationship between perceived ICT competence and ICT autonomy in the presence of availability and use of ICT at school would suggest that attitudinal or competency-based measures of ICT need to be considered in their broader school and usage contexts.

The findings overlap with previous research by Tømte and Hatlevik (2011) in relation to gender differences in attitudes to ICT, showing female students had equal or higher interest in ICT than males. Furthermore, female students in Ireland were found to have the highest level of interest in ICT, compared with a set of comparison countries and OECD countries on average. However, this was not the case for competency-based measures such as perceived autonomy and competence in ICT, with female students rating themselves lower than their male counterparts. This is in line with previous research by Hatlevik et al. (2018) and by Aesaert et al. (2017). It is also consistent with gender differences observed on overall science performance in Ireland in PISA 2015 which showed females performing significantly less well on the computer-based assessment of scientific literacy than males (Shiel et al., 2016), with a difference (-10.5 score points) that was greater than the OECD country average (-3.5).

It may be the case that that there is an optimum level of ICT use, as those in the highest quartiles on the attitudinal indices show lower performance. Lorenceau et al. (2019) highlight PISA 2015 findings that showed a negative correlation between ICT use at school and students' performance in mathematics, science and reading. Furthermore, these authors present evidence of a 'bell-shaped' relationship between print and digital reading in 2012 for ICT use across a cohort of OECD countries, suggesting that a moderate use of digital devices at school may be preferable to no use at all or very high levels of use (also see Hu et al., 2018). With recent efforts to embed digital technology in Irish post-primary classrooms as part of Ireland's Digital Strategy for Schools, Lorenceau et al.'s data suggest that a measured and deliberate approach incorporating digital technology in classrooms that focuses on the purposes of use and matching these to particular learning goals is appropriate. However, it is also clear that at the time of the PISA 2015 assessment, Irish students did not have the same access to devices as students on average across OECD countries, nor did they utilise technology inside and outside the classroom to the same degree. While Irish students reported high levels of perceived autonomy and competence in ICT, when other factors were taken into account, these indices had a negative relationship with science performance. The findings from the 2013 ICT Census (Cosgrove et al., 2014) point to a didactic approach to technology in classrooms at the time, with use often limited to instruction as opposed to a hands-on constructivist approach, which underpins the current *Digital Learning Framework* (DES, 2017). The results of the baseline evaluation of the *Digital Learning Framework* (Cosgrove et al., 2019) indicate positive engagement with digital technology for teaching, learning and assessment, coupled with a shift towards more collaborative approaches, and are an initial indication of how schools in Ireland are embedding digital technology into teaching, learning and school management.

There are also questionnaire-related limitations. Unlike PISA test items, PISA questionnaire responses were not examined for cross-country comparability, apart from what was established through the use of standardised procedures during data collection and analysis. In addition, while science was used as an outcome variable, the ICT questions did not focus specifically on science. It would have been useful to have direct feedback from students on their levels of engagement with the types of virtual experiments and simulations that featured in PISA 2015 science.

It is argued that the way in which ICT is used for educational purposes has a greater influence on academic achievement than the mere availability of ICT (DES, 2017). The observed negative relationship between school-level ICT use (and availability of ICT at the student-level) and science performance may seem inconsistent with efforts to embed ICT into teaching, learning and assessment in schools. However, other research suggests that moderate use of technology is positively associated with higher academic achievement (Lorenceau et al., 2019). With new ICT questions included in future cycles of PISA, drawing on updated and educationally contextualised student reports of use and dispositions, it is possible that a greater insight into the relationship between achievement and technology use will emerge.

While there is a need to examine how students at all ability levels use digital technology, the infrastructure and extent of ICT use in teaching and learning are also key. The baseline report on the *Digital Learning Framework* evaluation (Cosgrove et al., 2019) underlines issues facing post-primary schools that may hinder implementation; these include time pressure, teacher continuing professional development (CPD), challenges related to school infrastructure and maintenance, and the lack of technical support. This paper reports that students were not utilising ICT in class to the same extent as students on average across OECD countries. Reporting on students in Grade 8 TIMSS, Clerkin et al. (2018) also note that the use of ICT in post-primary mathematics and science lessons in Ireland is below TIMSS international averages.

The analysis presented in this paper contributes to the broader discussion of ICT use, attitudes and dispositions, and their relationships with student performance. However, the findings, when contextualised with the current policy setting and recent advances in questionnaire development, highlight the evolving nature of digital technology and the onus on researchers and questionnaire developers to capture relevant and up-to-date information on ICT use and attitudes.

While students must be digitally literate in relation to technology's functions, they (and educational stakeholders) must also gain a clear understanding of the role and limitations of digital technologies, both inside and outside of the classroom. This principle is also part of the Digital Learning Framework which defines digital competence in a wider sense, 'the set of skills, knowledge and attitudes that enable the confident, creative and *critical use* of digital technologies to enhance teaching, learning and assessment' (DES, 2017; p.16). The term 'critical use' has increasing importance and overlaps with aspects of the new reading literacy framework for PISA 2018, in which it forms part of the 'Evaluate and Reflect' reading literacy subscale (OECD, 2019). Teachers and schools, as well as parents and guardians and students themselves, have a role in facilitating the development of awareness and skills.

The ability of students to adapt to, and keep up with, developments in ICT is crucial for their future success both educationally and in real life (Cosgrove et al., 2018; DES, 2015; OECD, 2015). Findings from this paper highlight how students in Ireland may have a greater interest and perceived ability in ICT than on average across OECD countries. This suggests that there is an opportunity for the education system to harness this interest and engagement, yet these students may currently lack opportunities to apply their digital interests and skills critically and strategically to their educational development. The data also point to the importance of nurturing students' autonomy and competency in relation to ICT, particularly among female students, who, in Ireland, have just as much interest in ICT as male students but perceive themselves to be less competent and less autonomous. This is particularly relevant in the context of the 2015 science results in Ireland, with Irish females performing significantly less well than their male counterparts in the science domain, with a larger gender difference than across most other OECD countries (Shiel et al., 2016).

It is clear that discussion about the relationships between several aspects of ICT (availability, use and attitudes) and student performance will continue with the growing ubiquity of digital technology in education, work and everyday life. With PISA and other national and international studies, as well as standardised and other forms of testing, moving from paper to computer assessment, attention is drawn to countries in which there is more limited use of ICT in teaching, learning and assessment (or where certificate examinations are conducted on paper), as the development of digital skills may not be happening to the same extent as for students in countries with high levels of technology embedded into their education systems. Irish educational policy has moved forward since the results in PISA 2015, with the *Digital Strategy* and the *Digital Learning Framework* supporting increased use of technology in post-primary classrooms. However, there may be value in extending use of ICT in assessment, including for classroom-based assessments or assessment tasks at Junior Cycle, to support the measured approach evident in the policy framework, and to better prepare students in Ireland to work and live in a society in which most tasks are now conducted using digital devices.

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Appendix

TABLE A1

Student Access to and Use of ICT – Ireland and OECD Average – Standard Errors

Index		Mean Scores (SE)	DEIS & Non-DEIS Schools (SE)	School Type (SE)	Correl. with SCI (SE)	Science Performance by ICT Index Quartiles (SE)
Availability of ICT in school	IREL	(0.06)	DEIS Schools (0.13) Non-DEIS Schools (0.07)	Girls' Sec (0.14) Boys' Sec (0.12) Mixed Sec (0.16) Com/Comp (0.15) Vocat. (0.12)	(0.02)	Q1 (3.45) Q2 (3.12) Q3 (3.13) Q4 (3.54)
	OECD	(0.01)	N/A	N/A	(0.00)	Q1 (1.11) Q2 (0.67) Q3 (0.61) Q4 (0.73)
Use of ICT at school in general	IREL	(0.03)	DEIS Schools (0.03) Non-DEIS Schools (0.03)	Girls' Sec (0.05) Boys' Sec (0.04) Mixed Sec (0.11) Com/Comp (0.04) Vocat (0.04)	(0.02)	Q1 (3.37) Q2 (2.68) Q3 (2.75) Q4 (4.04)
	OECD	(0.00)	N/A	N/A	(0.00)	Q1 (1.06) Q2 (0.69) Q3 (0.63) Q4 (0.86)

***TABLE A1** (contd.)*

Student Access to and Use of ICT – Ireland and OECD Average – Standard Errors

Index		Mean Score	Difference DEIS & Non-DEIS Schools	Mean by School Type	Correl. with SCI	Difference in Science Performance by ICT Index Quartiles
Use of ICT outside of school, for school-work	Ireland	(0.02)	DEIS Schools (0.06) Non-DEIS Schools (0.03)	Girls' Sec (0.03) Boys' Sec (0.03) Mixed Sec (0.09) Com/Comp (0.04) Vocat (0.04)	(0.02)	Q1 (3.60) Q2 (3.08) Q3 (2.60) Q4 (3.90)
	OECD	(0.00)	N/A	N/A	(0.00)	Q1 (0.84) Q2 (0.59) Q3 (0.65) Q4 (0.72)

TABLE A2

Students' Attitudes to ICT and Science Performance – Ireland and OECD Average – Standard Errors

Index		Mean Score (SE)	Gender Mean Score (SE)	Correl. w/ SCI (SE)	ESCS Quartiles (SE)	Science Quartile (SE)
Interest in ICT	IREL	(0.03)	Males (0.02) Females (0.02)	(0.02)	Q1 (0.03) Q2 (0.03) Q3 (0.02) Q4 (0.02)	Q1 (7.25) Q2 (2.86) Q3 (2.93) Q4 (3.13)
	OECD Avg	(0.07)	Males (0.00) Females (0.00)	(0.00)	Q1 (0.01) Q2 (0.01) Q3 (0.01) Q4 (0.00)	Q1 (0.78) Q2 (0.59) Q3 (0.62) Q4 (0.62)
Perceived ICT Autonomy	IREL	(0.18)	Males (0.02) Females (0.02)	(0.02)	Q1 (0.03) Q2 (0.03) Q3 (0.03) Q4 (0.03)	Q1 (3.27) Q2 (3.49) Q3 (3.42) Q4 (3.26)
	OECD Avg	(0.14)	Males (0.00) Females (0.00)	(0.00)	Q1 (0.01) Q2 (0.01) Q3 (0.01) Q4 (0.01)	Q1 (0.64) Q2 (0.66) Q3 (0.65) Q4 (0.66)
Perceived ICT Competence	IREL	(0.12)	Males (0.02) Females (0.02)	(0.02)	Q1 (0.03) Q2 (0.03) Q3 (0.02) Q4 (0.03)	Q1 (3.51) Q2 (3.01) Q3 (3.47) Q4 (3.28)
	OECD Avg	(0.01)	Males (0.00) Females (0.00)	(0.00)	Q1 (0.01) Q2 (0.01) Q3 (0.01) Q4 (0.00)	Q1 (0.82) Q2 (0.61) Q3 (0.63) Q4 (0.62)

TABLE A3

Mean Scores and Standard Errors on ICT Access/Use and Attitudinal Indices, by Country and OECD Average

Country	Perceived Interest in ICT		Perceived ICT Autonomy		Perceived ICT Competence	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Australia	0.18	(0.01)	0.12	(0.01)	0.21	(0.01)
Germany	0.05	(0.01)	0.2	(0.02)	-0.05	(0.01)
Ireland	0.32	(0.02)	0.11	(0.02)	0.21	(0.01)
Korea	-0.37	(0.02)	-0.38	(0.02)	-0.57	(0.02)
Netherlands	0.05	(0.02)	-0.02	(0.01)	-0.04	(0.01)
OECD Avg.	0.01	(0.00)	0.01	(0.00)	0.34	(0.02)

TABLE A3 *(contd.)*

Mean Scores and Standard Errors on ICT Access/Use and Attitudinal Indices, by Country and OECD Average

Country	Availability of ICT at School		ICT Use at School in General		ICT Use Outside of School for Homework	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Australia	7.60	(0.03)	0.56	(0.01)	0.16	(0.01)
Germany	---	---	-0.42	(0.02)	-0.38	(0.01)
Ireland	5.91	(0.06)	-0.38	(0.03)	-0.42	(0.02)
Korea	5.62	(0.07)	-0.95	(0.03)	-0.34	(0.02)
Netherlands	6.96	(0.05)	0.44	(0.02)	0.17	(0.01)
OECD Avg.	7.60	(0.03)	0.56	(0.01)	0.16	(0.01)

TABLE A4

Mean Scores and Mean Score Differences on Attitudinal Indices, by Gender, Ireland, Comparison Countries and OECD Average

Country	Perceived Interest in ICT				Perceived ICT Autonomy			
	Female		Male		Female		Male	
	Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)
Australia	0.18	(0.02)	0.18	(0.02)	-0.13	(0.01)	0.38	(0.01)
Germany	-0.03	(0.02)	0.13	(0.02)	-0.19	(0.02)	0.6	(0.02)
Ireland	0.34	(0.02)	0.30	(0.02)	-0.09	(0.02)	0.3	(0.02)
Korea	-0.31	(0.02)	-0.42	(0.03)	-0.49	(0.02)	-0.27	(0.03)
Netherlands	0.03	(0.02)	0.07	(0.02)	-0.26	(0.01)	-0.22	(0.02)
OECD Avg.	-0.02	(0.00)	0.04	(0.00)	-0.24	(0.00)	0.25	(0.00)

TABLE A4 *(contd.)*

Mean Scores and Mean Score Differences on ICT Access/Use and Attitudinal Indices, by Gender, Ireland, Comparison Countries and OECD Average

Country	Perceived ICT Competence			
	Female		Male	
	Mean	(SE)	Mean	(SE)
Australia	0.08	(0.01)	0.33	(0.01)
Germany	-0.35	(0.02)	0.26	(0.02)
Ireland	0.11	(0.02)	0.31	(0.02)
Korea	-0.67	(0.02)	-0.48	(0.02)
Netherlands	-0.20	(0.02)	0.13	(0.02)
OECD Avg.	-0.16	(0.00)	0.18	(0.00)

TABLE A5

Mean Scores Differences by Gender, t Scores and p Values for ICT Access/Use Indices, Ireland, Comparison Countries and OECD Average

Country	Availability of ICT in School				ICT Use at School in General			
	Diff	(SE)	t	p.	Diff	(SE)	t	p.
Australia	0.02	(0.01)	2	<0.05	0.06	(0.01)	6	<0.01
Germany	--	--	--		-0.12	(0.02)	-6	<0.01
Ireland	-0.12	(0.02)	-6	<0.01	-0.11	(0.02)	-5.5	<0.01
Korea	0.06	(0.02)	3	<0.01	-0.11	(0.03)	-3.7	<0.01
Netherlands	-0.13	(0.03)	-4.3	<0.01	-0.06	(0.02)	-3	<0.01
OECD Avg.	-0.08	(0.00)	8	<0.01	-0.12	(0.00)	12	<0.01

***TABLE A5** (contd.)*

Mean Scores Differences by Gender, t Scores and p Values for ICT Access and Use Indices, Ireland, Comparison Countries and OECD Average

Country	ICT Use Outside of School, for Schoolwork			
	Diff	(SE)	t	p.
Australia	0.02	0.01	2	<0.05
Germany	-0.07	0.02	-3.5	<0.01
Ireland	-0.05	0.02	-2.5	<0.01
Korea	0.08	0.02	4	<0.01
Netherlands	0.02	0.02	1	ns
OECD Avg.	-0.08	0	8	<0.01