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A Global View of What Fixes Information Technology Skills Shortage: Panel Data Analyses of Countries' Human and Technology Resources

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Abstract

This paper aims to provide evidence of what fixes the information technology skills shortage. The focus is on countries' workforce development factors, i.e., human and technology. The research model was tested using secondary data from multiple sources. An ordinary least square with panel corrected standard errors was used to analyze the data. The results indicate that organizations' staff training and gender parity among science, technology, engineering, and mathematics graduates relate negatively to IT talent shortage; this is consistent in both models the authors tested. This study contributes to the IT workforce literature by being the first study that empirically examines the relationships between IT skills shortage and the relevant workforce development factors. Besides, objective measures of IT skills shortage were used, thus overcoming issues that might arise from using the subjective ones, such as counting the number of IT job openings based on predetermined occupation codes. For policymakers wanting to fix the IT skills shortage, the results revealed factors that can help fix the issue in the short term. Future research could examine other factors, such as policy or gender parity in IT careers if appropriate data is available.

Keywords: IT workforce, skills shortage, STEM workforce, workforce development, human and technology resource

Introduction

Information technology (IT) skills shortage is a barrier that prevents businesses and nations from achieving the level of productivity and performance they target (Goodwin, 2018; Khan & Sikes, 2014; McKinsey & Company, 2016). So IT skills shortage has been an important topic for policymakers, educators, and business managers in several countries. The IT skills shortage exists when businesses and organizations have difficulty filling IT job openings (Blumenstyk, 2018; Cukier, 2003; Trauth, 1999). In the past, IT skills shortage was a problem mainly in advanced economy contexts, such as in European countries (Bradbury, 2017) or the US (Freeman & Aspray, 1999). However, in the past few years, the growing digital economy makes

IT skills shortage a global phenomenon. According to the Manpower Group's Annual Talent Shortage Survey conducted in over 40 countries, IT staff members have remained in the top ten hardest jobs to fill since the year 2011. IT roles jumped seven places to the second hardest position to fill globally. Such that, the inability to retain skilled professionals was a major cause of IT staff shortage in South Africa (Plaatjies & Mitrovic, 2014) and Singapore (Weizhen, 2016). To leverage the evolving digital economy, business and public sectors in many countries have tried to find ways to tackle the IT skills shortage issue. For instance, Japan worked with India to fill the shortage by targeting their IT training strategy (NIKKEI Asian Review, 2016). In Canada, the Information and Communications Technology Council started an initiative to solve the shortage by encouraging collaboration between the education and the industry sectors (Arellano, 2015).

Even though the IT skills shortage is a global phenomenon, the scope of IT job roles varies across sources. In this study, the range of IT job roles come from two sources: Manpower Talent Shortage Survey and Harvey Nash / KPMG CIO Survey. Harvey Nash / KPMG CIO Survey's IT functions include data/analytics, technical architecture, security and resilience, enterprise architecture, business analysis, project management, and development (Harvey Nash / KPMG, 2016). Manpower Group's Annual Talent Shortage 2016 (ManpowerGroup, 2016) describes IT staff as developers, programmers, database administrators and IT leaders and managers. Hence, IT job roles relate to the management and development of information technology infrastructure and applications, as well as analysis of business information system and data analytics.

IT skills shortage is a complex phenomenon, conflicting perspectives regarding its causes and solutions can be found in magazines and trade presses. Oxford Economics (2015) found that almost 30 major economies are unprepared for the growing need for technology skills. Securing human capital is a challenge in the IT field because of the ever-changing demand for skills and the rise of the gig economy (Gunnion, 2016). Moreover, the problem of not enough women in the IT field and higher education has arisen as common causes of IT skills shortage (Overture Partners, 2017; The Economist, 2016). Some blame IT education for not teaching necessary skills markets need (Bidwell, 2013). Others blame businesses for not investing enough in human resources (Ryan, 2015) or not revising their recruitment strategies. Traditional channels in recruiting candidates still work, but recruitment through social media has shown to be more effective in hiring qualified IT professionals (Eckhardt & Laumer, 2009; Lonergan, 2016; Rienties, Tempelaar, Pinckaers, Giesbers, & Lichel, 2012). Some employment statistics, at least at the surface, contradicts the IT skills shortage claims. For instance, a survey by Georgetown University (2013) found that recent information systems (IS) graduates in the US have the highest rate of unemployment at 14.7 percent (up from 11.7 percent in 2012). This might indicate a broken link between recruiters and IT graduates or suggest that the IT higher education institutions are not preparing the workforce that meets the market's needs. This is a gap that could be filled even though education and IT careers has been an important research area for many years (Balfour, 1998; Beckett, 1985) and improving educational quality has been recommended by many IS scholars (Bailey & Stefaniak, 2000; Moe & Sein, 2001).

Regarding remedies of the above problem, a tech-savvy economist, Bessen (2014) explained that higher education alone could not fix the IT shortage problem; employers must also come up with business models that support on-the-job training for IT staff members. In the IT workforce development literature, the scholars have uncovered various factors that can help address the IT skill shortage issue. In addition to the factors mentioned above, lowering institutional barriers (such as degrees of qualified IT professionals) that are shown to prevent women from entering or

staying in IT careers can help increase the IT workforce (Cukier, 2003; Trauth, Quesenberry, & Huang, 2009). Beside gender, understanding differences in ethnicity would also help attract IT candidates and reduce staff shortages (Trauth, Cain, Joshi, Kvasny, & Booth, 2012). However, there has been no systematic and deliberate effort at modeling the effects of these factors on IT skills shortage at the country level.

In summary, in recent years, the IT skills shortage has spread globally, and a cross-country study on relevant factors will shed light on critical country-level factors that could potentially help ameliorate the shortage issue. Examining this will contribute to both practice and IT workforce development literature. Therefore, the underlying question for this study is as follows: *What is the link between workforce development factors and a country's IT skills shortage?* To answer the research question, the authors tested the relationship between a country's technological infrastructure, education, training, and gender parity (workforce development factors) as in the IT field and the level of IT skills. It is hoped that the finding would benefit educators, policymakers and business managers in addressing the skills shortage issue.

The remaining of this paper is organized as follows. First, the authors summarize the literature examining the IT skills shortage and highlight critical factors relevant to the IT skills shortage. Then, the methods of answering the question posed are described. The findings are presented next. The paper is concluded with result discussions, limitations and potential for future research.

Literature Review and Hypothesis Development

IT Skills Shortage

An IT skills shortage exists when organizations have difficulty filling IT job openings (Cukier, 2003; Trauth, 1999). There are two common measures of IT skills shortage. The first is the number of IT job openings that remain unfilled for a certain period, such as six months (Bennett, 2002; Shah & Burke, 2005; Weitzel, Eckhardt, & Laumer, 2009). In general, an objective measure is preferred, because one could argue that it is less biased compared to a subjective one. However, in the case of the IT skills shortage, while using an objective measure such as advertising IT job openings, measurement techniques used in data collection were a concern, especially in determining occupation codes used to identify the facets of an IT career (Battistel, 2009). In recent years, the titles of IT jobs have become more diverse, and it has become harder for scholars to determine IT skills shortages by reviewing advertisements.

The second involves subjective measures, such as numbers reported by people who are involved in the IT staff recruiting process. However, at the country level, there are only a few measures available: Manpower Group's Annual Talent Shortage Survey (Talent Shortage Survey) (ManpowerGroup, 2016) and Harvey Nash / KPMG's Annual CIO Survey (CIO Survey) (Harvey Nash / KPMG, 2016). The Talent Shortage Survey data was among the most cited one, such as by the OECD (2016) and CEDEFOP-European Union (2015), but only the percentages of countries' overall shortage were used (Gordon, 2009; Schuler, Jackson, & Tarique, 2011). These kinds of measures would add insight and new knowledge to the literature examining the IT skills shortage. So far, the country-level IT skills shortage (reported by CIOs and business managers) has not been quantitatively analyzed in scholarly work, and leveraging this measure is one of the contributions of this study.

Factors Relating to Information Technology Skills Shortage

Studies examining IT skills shortage began to be performed in the 1980s (Ashworth, 1985) and many factors were examined, mostly qualitative or descriptive. Factors include education, gender parity, organizational human resource development, technological infrastructure, academic-business collaboration, and educational policy (Breznitz & Feldman, 2012; McDaniel, 2013; Trauth, 2007). These factors are essential in the context of workforce development, which encompasses many different areas of education, training, and business activity, and also relate to the areas of technology, globalization, and new economy (Jacobs & Hawley, 2009). Workforce development is often highlighted in debates on IT skills shortages regarding the need to increase the pool of skilled workers in critical industries (Harris & Short, 2014). From the review, most studies examining IT skills shortage focused on the area of workforce development. Some studies were not entirely relevant to workforce development, such as the one focusing on firms' recruiting processes (Eckhardt & Laumer, 2009; Ferratt, Agarwal, Moore, & Brown, 1999). To keep the study at a manageable size, the authors will focus on the literature at the intersection of IT skills shortage and workforce development. The following section list what previous studies have found about workforce development factors that relate to IT skills shortage.

Education

Higher education is at the heart of IT skill shortage issue (Leahy & Wilson, 2014; White, Hewitt, & Kruck, 2013). The literature attributes the shortage in the supply of IT graduates (Cohen, 1987; Walstrom & Schambach, 2012) and deficiencies in the higher education system to the IT skills shortage, such as in the UK (Ashworth, 1985) and Canada (Balfour, 1998). When solving the shortage issue by focusing on education, two dimensions need to be addressed – a quality of IT education and quantity, i.e., broadening the participation in the IT workforce. From the quantity standpoint, a case study by O'Donnell (2004) showed that expanding IT education to disadvantaged students helped to reduce the staffing shortage in Europe. In addition, updating skill set (Huang, Kvasny, Joshi, Trauth, & Mahar, 2009; Leahy & Wilson, 2014), continuously improving curriculums (Asgrahani & Shankararaman, 2014; Fichman, Dos Santos, & Zheng, 2014; Golshani, Panchanathan, Friesen, Park, & Song, 2001; Zwieg et al., 2006), and making sure curriculums are market-driven were action points suggested by many researchers (White et al., 2013; White & Lester, 2002). Hence, the authors can hypothesize the following hypotheses:

- H1a: A country's quality of education has a significant negative impact on IT skills shortage.
- H1b: A country's quantity of education has a significant negative impact on IT skills shortage.

Training

In addition to formal education, continuous learning or training in organizations is suggested as a practical solution (Baron, 2000; Bedford, 2003; Janz & Nichols, 2010). Training in this study includes continuous learning in organizations (or investment organizations made through human resource development) with a goal of building knowledge and skills to facilitate job performance (McDaniel, 2013). At the same time, in the digital era, businesses need to incorporate human resource development processes in planning organizational strategies in order to successfully meet their IT needs (Moe & Sein, 2001). However, training does not have to be only about computer hardware or software; research showed that soft skills were as necessary as hard skills

to be successful in IT and science, technology, engineering, and mathematics (STEM) fields (French, Gotch, Immekus, & Beaver, 2016; Joshi & Kuhn, 2007). Hence, the authors develop the next hypothesis as:

- H2: A country's organizational training has a significant negative impact on IT skills shortage.

Gender Parity in IT

Gender parity in the IT field exists when women are not underrepresented (Trauth, Nielsen, & Von Hellens, 2003; Trauth & Quesenberry, 2007). Recruiting and retaining women in IT careers has been a challenge in many countries, and attracting more women into IT and STEM fields are suggested as a remedy for IT skills shortage (Shortt & O'Neill, 2009; Trauth et al., 2003). Cukier (2003) found that many institutional factors prevent women from staying in IT careers. For example, there was a discrepancy between skill requirements for IT jobs and qualifications sought by recruiting managers. Computer science or engineering degrees was commonly required, but a survey by Wired Women Association revealed that only a fraction of current female IT professionals were computer scientists, and none are engineers. To solve the IT skills shortage in Canada, organizational structure relating to IT roles must become women-friendly. South Africa solved the shortage problem by making sure that IT education is inclusive of girls (Dlodlo, 2009). Therefore, the authors hypothesize that:

- H3: A country's gender parity in IT has a significant negative impact on IT skills shortage.

Technological Infrastructure

Technological infrastructure refers to IT used by both firms and individuals in a country. Prior research argues that investing in the technological infrastructure in schools can solve the IT skills shortage in a country. However, many barriers, such as cost and poor policies, especially in developing countries, were found to impede such solutions (Ewusi-Mensah, 2012; Hawking, 2010). The IT shortage in developed countries such as the US and UK (Janz & Nichols, 2010; Leahy & Wilson, 2014), suggests that merely the presence of good technological infrastructure does not result in a higher number of qualified workers. In recent years, countries have globally improved their technological infrastructure in order to take advantage of the evolving digital economy and also to fix the shortage of a qualified workforce problem (Holtgrewe, 2014). The extent to which technological infrastructure can help in fixing the shortage issue remains to be examined. This leads to the last hypothesis:

- H4: A country's technological infrastructure has a significant negative impact on IT skills shortage.

Most studies examining the IT skills shortage are case studies in a single country, mostly Canada, the UK, Australia, and the US. Quantitative studies modeling the impact of the factors mentioned above on IT skills shortage is absent, perhaps due to the challenges of obtaining country-level data. Since the IT skills shortage is not just a phenomenon in developed countries, but also in developing countries such as South Africa and India. The authors hope that this study presents rigorous evidence to the discussion of the IT skills shortage. Next section is the discussion on the data collection and analyzes.

Method

Data Collection

To measure the variables, the authors looked at existing data in different databases. First, they tried to find the best measure of the dependent variable: IT skills shortage. There are a few measures on countries' skills index, such as Hays Global Skills Index (HAYS, 2016) and INSEAD's Global Talent Competitiveness (INSEAD, 2016). After extensive review, the authors found two best measures, which came from Manpower Group's Annual Talent Shortage Survey (Talent Shortage Survey) (ManpowerGroup, 2016) and Annual CIO Survey of Harvey Nash / KMPG (CIO Survey) (Harvey Nash/KPMG, 2016). The CIO Survey is the largest IT leadership survey in the world regarding the number of respondents. In 2016, Harvey Nash / KPMG surveyed 3,352 CIOs and technology leaders between December 12, 2015, and April 10, 2016, across 82 countries. This survey has been conducted annually since the year 2005. For the Talent Shortage Survey, Manpower Group surveyed more than 41,700 hiring managers in 42 countries to identify the proportion of employers having difficulty filling positions, which jobs are challenging to fill, and why. Employers were also asked about the impact talent shortages have on their organizations and what steps they are taking to address them. This survey has been conducted annually since 2006.

Next, the authors determined measures for the independent variables; they looked at databases of World Bank, World Economic Forum (WEF), United Nations Educational, Scientific and Cultural Organization (UNESCO), and Oxford Economics. The measures came from three different datasets of WEF, which are the Networked Readiness Index (NRI), the Global Competitiveness Index (GCI), and the Gender Gap Index (GGI). The NRI measures were originally developed by the Information Technology Group worked at Harvard University's Centre for International Development until 2002 (Eggleston, Jensen, & Zeckhauser, 2002). In 2003, WEF collected the first dataset using those measures, in collaboration with INSEAD and infoDev; and the measures were revised from time to time. Currently, the NRI dataset includes nine groups of measures: political and regulatory environment, business and innovation environment, infrastructure, affordability, skills, individual usage, business usage, government usage, economic impacts, and social impacts (WEF, 2016a).

The NRI dataset partly came from UN agencies, such as the World Bank, UNESCO, and International Telecommunication Union (ITU). Another part of the dataset was derived from WEF's annual Executive Opinion Survey (EOS). It captured the opinions of over 14,000 business leaders in over 140 countries. The Survey was available in over 40 languages, of which, about half is available online. The Survey is divided into 15 sections: about your company, most problematic factors for doing business, infrastructure, technology, financial environment, foreign trade and investment, domestic competition, business operations and innovation, security, governance, education and human capital, health, travel and tourism, environment, and risks. Most questions in the Survey ask respondents to evaluate on a scale of 1 (worst possible situation) to 7 (best). The administration of the Survey was carried out via the network of over 160 WEF's partner institutes worldwide. Recent research showing the richness of the NRI data include Datta (2011), Pick and Azari (2011), and Watanabe, Naveed, and Neittaanmäki (2015).

About CGI, WEF has been evaluating countries' competitiveness since 1979, which started as a research project by Professor Klaus Schwab (WEF, 2016b). In 1979, the analysis included 16 European countries. The underlying concept of this study was Schwab's innovative concept of

competitiveness, which included the ability of enterprises as well as the traditional notion of labor and capital productivity. There were 200 indicators in the first year, 50 were derived from the survey. Thirty-five years later, the GCI cover over 140 economies and assess several key drivers of development. The methodology used to conduct the assessment was available starting the year 2005. The objective of CGI stays the same since 1979, which was to support policymakers and business leaders in their efforts to formulate improved economic policies and institutional reforms. In parallel with the development index, the original survey that started in 1979 is now called the Executive Opinion Survey. The data from this survey is also used in NRI, and the detail of the survey is explained above. The CGI gathered comprised 12 'pillars' as follow: Institutions, infrastructure, Macroeconomic environment, Health and primary education, Higher education and training, Goods market efficiency, Labor market efficiency, Financial market development, Technological readiness, Market size, Business sophistication, and Innovation (WEF, 2016c). The publication of the report each year attracts considerable public interest and has been a flagship of the WEF's institutional success, and this dataset has been leveraged in business and management's scholarly work, such as in hospitality and tourism (Crouch, 2007), business ethics (Gugler & Shi, 2009), and a few in IS (Alderete, 2017; Chakraborty & Kumar, 2013).

For the GGI, since 2006, WEF's GGI has been used as a global benchmark for gender parity progress. GGI has been tracking the divide between women and men's parity in employment, education, health, and politics (WEF, 2016d). The methodology and quantitative analysis used are intended to serve as a basis for designing effective measures for reducing gender gaps. The methodology of the Index has remained stable since 2006, providing a basis for robust cross-country and time-series analysis (WEF, 2016d). Indicators came from multiple sources: International Labor Organization (ILO), WEF's Executive Opinion Survey, UNESCO, Central Intelligence Agency's (CIA) Factbook, World Health Organization, and Inter-Parliamentary Union. Recent IS research employing this dataset includes, for example, Eneh (2010), Nord, Riggio, and Paliszkiewicz (2016), and Goyal (2011).

The sample included 28 countries in one model with IT skills shortage measure came from the CIO Survey, and 39 countries in another model that leverage a measure from the Talent Shortage Survey. Only a complete case (no missing data) is included in the analyses. Even though the surveys and indexes that the measures came from are available for several years, the measures (the dependent variable and the GGI's Female STEM graduates) used in this study are available only a few years back. Thus, the data covers only recent years, 2014 – 2016; and some countries have only one observation. See Appendix 2 for countries included in the analyses. Countries that are in bold font are included in the analyses of Model 1 and Model 2.

Dependent Variables

There are two measures for IT skills shortage. The first measure is the percentage of CIO in a country reporting technology skills shortage. A country is included in the analysis if there were at least 10 CIOs participated in a particular year. This data is not publicly published. Harvey Nash / KPMG shared the technology skills shortage dataset per the authors' request. The second measure came from the Talent Shortage Survey. Each year, Manpower Group published the ranking of the "top ten jobs to fill" for about 40 countries they surveyed. The top of the hardest job to fill ranked 1 in the survey and 10 was the least-hardest job to fill. In this analysis, the original 1 to 10 is re-coded to make the value 10 the top hardest job to fill and 1 the least-hardest to fill. For example, in 2016, *IT Personnel* ranked number 10 for the US, so in this analysis, the

US's 2016 is coded to 1. Country's value is coded 0 if *IT Personnel* was not in the top ten hardest jobs to fill. For example, Peru's 2016 list of top ten hardest jobs to fill did not have IT Personnel, so Peru's 2016 value is 0.

Independent Variables (Workforce Development Factors)

Education

There are two variables in measuring a country's education – quantity and quality. Quantity is captured as the of education is an average score of secondary and tertiary education enrolments in gross percentages of the population of the age group that officially corresponds to the secondary and tertiary education level. Then WEF transformed these percentages to the scale of 1-7 (best) using min-max transformation. For the quality of education, an average of the following four indicators is used: quality of the education system, quality of math and science education, quality of management schools, and Internet access in schools. WEF defined the quality of education as for how well the education system meets the needs of a competitive economy; and to build a competitive economy, both STEM and management skills are needed. Therefore, the quality of management schools is included in a list of indicators. All these were collected from the Annual Executive Survey. The scale is 1-7 (best) for all four indicators. The average scores of both quantity and quality of education (scale of $1 – 7$, best) came directly from WEF's Global Competitiveness dataset.

Training

The measure of the training and development came directly from WEF's Network Readiness dataset. The authors used staff training score at the firm-level which was collected from the WEF's annual Executive Opinion Survey. WEF asked firm executives: In your country, to what extent do companies invest in training and employee development [1 = not at all; 7 = to a great extent]?

Gender Parity in IT

To measure gender parity in IT field, the ratio of female/male STEM graduate was found to be the most representative since country-level numbers of IT graduate is not available. The authors retrieved the number of male and female STEM graduate from WEF's Gender Gap Index and computed the parity by dividing the number of females by male STEM graduate. The value of 1 means that there was an equal number of male and female graduates in that particular year. WEF calculated the percentage of tertiary-level STEM graduates, (female, male) using data from UNESCO Institute for Statistics (UIS) database. Measures the percentage of female and male graduates in ISCED 6 and ISCED 7 programs from Science, Engineering, Manufacturing and Construction (% of total number of graduates). For example, for New Zealand 2016 STEM graduate, 11% (out of the total number of graduates) were female and 30% were male, the value of New Zealand 2016 in the analysis is 11/30, or 0.367. Note that, even though the Gender Gap data has been collected annually since 2006, but STEM graduate is available only from 2014.

Technological Infrastructure

To measure IT used by both firms and individuals, the authors used a country's technological readiness score (1-7 best), which came directly from WEF's Global Competitiveness Index. This

score is an average score of seven indicators shown in Appendix 1. The first three indicators were collected from WEF's annual Executive Opinion Survey and the scale is 1-7 (best). Another four indicators were collected from various databases of UN agencies and their scales were normalized to 1-7 (best) using a min-max transformation method.

Control Variables

This study is controlled for a country's average income and the gross domestic product valued at purchasing power parity in billions of international dollars or GDP (PPP$ billions) is used as a measure. This measure was widely used in country-level studies in business and management field (Cullen, Johnson, & Parboteeah, 2014; Ganju, Pavlou, & Banker, 2016). In the literature, income was viewed to be one of the primary causes of shortage because it prevented people to access to IT-related education and training (Dlodlo, 2009; Fusilier & Durlabhji, 2008). This study focuses on workforce development related factors, so the authors chose not to explain the variation in IT skills shortage caused by a country's average income. GDP (PPP$ billions) came directly from WEF's Global Competitiveness Index but was initially been collected by the World Bank. Appendix 1 shows variables, measures, and their sources.

Data Analyses

Because this study uses an unbalanced panel-data, there are potential econometric problems of heteroskedasticity across countries and autocorrelation across time. The data is at country-level, and some countries had only one observation and pooled ordinary least squares (OLS) regression might be possible. However, OLS may be problematic in the presence of heteroskedasticity and autocorrelation. Although the OLS estimators are unbiased and consistent, they are not efficient, and the standard errors are not correct (Greene, 2003). To deal with these issues, the authors can use a feasible generalized least square (FGLS, or *xtgls* command in Stata) to correct the standard error (Wooldridge, 2010). However, Beck and Katz (1995) suggested that in working with cross-sectional time-series data, researchers should use OLS with heteroskedastic panels corrected standard errors (OLS-PCSE, or *xtpcse* command in Stata), because the standard errors of the estimated coefficients based on FGLS may underestimate the true sampling variability. Their Monte-Carlo analysis shows that OLS-PCSE performs better than FGLS in estimating the standard errors. The OLS-PCSE can avoid extreme overconfidence often associated with the popularly-used FGLS estimator in the case of panel data sets in which the total time period T is smaller than total section N. Another advantage of this technique is that it allows for disturbances that are heteroskedastic and contemporaneously corrected across panels.

The authors employed *casewise* option associated with the *xtpcse* command in Stata (ver. 14) to include only observations with complete cases. Given the moderately high correlations among TI, Edu_Qual, and TRA, the authors used the variance inflation factor (VIF) statistics after the regression to check for multicollinearity. No variable whose VIF value is greater than 10 and no tolerance value (1/VIF) is lower than 0.1, this suggests that multicollinearity was not a problem (UCLA IDRE, 2017a). For heteroskedasticity, the authors used Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (UCLA IDRE, 2017b). For both models, p-value was not significant (greater than .05), so the authors accepted the null hypothesis of the test that the variance is homogeneous. Since the presence of heteroskedasticity is not an issue in the models, the authors chose not to use 'hetonly' option of the *xtpcse* command in Stata (StataCorp LP, 2013). This option assumes panel-level heteroskedastic errors.

For robustness, the authors used two measures (CIOs' perspective and managers'/recruiters' perspective) for the dependent variable, in Model 1 and 2 separately. In both models, the authors examined the relationship between IT skills shortage (ITSS) and its relevant factors: technological infrastructure (TI), quality of education (Edu_Qual), quantity of education (which is measured by the country's enrolment percentage in secondary and tertiary education: EPST), training (TRA, and gender parity in STEM graduate (GP). This study is controlled for the country's average income using GDP as a measure.

Findings

Appendices 3 and 4 show a matrix of correlations and sample statistics for variables used in Models 1 and 2 respectively. As mentioned in the previous section, the correlation between a set of variables is moderately high, but the VIF stats indicate that multicollinearity is not a concern here. Table 1 shows the resulting relationships of both models. For Model 1, the independent variable is the percentage of CIO in a country that has reported a shortage of IT skills. Factors that have a negative relationship with ITSS are EPST, TRA, and GP. Edu_Qual is positively related to ITSS, and the relationship between ITSS and IT is not significant. Model 2, the independent variable, is a country's ranking of *IT Personnel* in the top 10 hardest jobs to fill. Factors that have a negative relationship with ITSS are TRA and GP; the relationships of other variables are non-significant. In both models, TRA and GP relate to ITSS negatively and significantly. The control variable of income is statistically significant under Model 1, but not in Model 2.

Table 1. Panel-Corrected Linear Regression Result

	IT Skills Shortage (ITSS)	
Variable	**Model 1** **CIO's perspective** **(percentage)**	**Model 2** **Recruiters'/Managers' Perspective** **(ranking 0-10)**
GDP (PPP$ billions) (GDP)	**2.48e-06*** (1.80e-07)**	0.0000116 (0.0000591)
H1a: Enrolment Percentage in Secondary and Tertiary Education (EPST)	*-0.079*** (0.005)*	0.361 (0.330)
H1b: Quality of Education (Edu_Qual)	**0.049*** (0.007)**	0.310 (0.557)
H2: Training (TRA)	*-0.070*** (0.015)*	*-0.667*** (0.101)*
H3: Gender Parity in STEM Graduates (GP)	*-0.219** (0.074)*	*-2.086* (0.981)*
H4: Technological Infrastructure (TI)	0.006 (0.011)	-0.757 (0.673)
Constant	1.313*** (0.094)	7.209*** (1.959)
Observation	57	92
Number of groups	28	39
R-squared	0.290	0.050
Estimated autocorrelation	0	0
Wald chi2(3)	445.17***	39.98***

No autocorrelation found in any of the two models and the significant Wald chi2 indicates good fitting models. The significant Wald test indicates that the coefficients of the included variables are not simultaneously equal to zero, meaning that including these variables creates a statistically significant improvement in the fit of the model (UCLA IDRE, 2017b). For the R^2, Model 1, the included variables explain about 29% of the variance in IT skills shortage. However, in Model 2, the variance in IT skills shortage is explained only at 5%. That means TRA and GP explain 5% of why IT skills were ranked differently across countries. However, in Model 1, GDP, EPST, Edu_Qual, TRA, and GP collectively explain 29% the proportion of CIOs reporting skills shortage across countries.

Conclusions

The authors have taken some initial first steps to analyze the relationships between the human and technology resources and IT skills shortage at the country level. Using the two best measures of the IT skills shortage from Manpower Group and Harvey Nash/KMPG, the results show that gender parity in STEM graduates and organizational training could potentially immediately help in reducing a country's IT skills shortage.

Model 1 shows a significant negative relationship between the quantity of education and the IT skills shortage (H1a is supported in Model 1), but Model 2 shows a non-significant relationship (H1a is not supported in Model 2). This might due to the cumulative education in 28 countries included in Model 1, which was more technology focused than that of the 39 countries in Model 2. Next, the hypothesis H1b is not supported in any of the two models. The positive relationship between the quality of education and the IT skills shortage in Model 1 does not mean that the quality of education was the cause of the shortage. Instead, in recent years, developed countries facing an IT skills shortage may be trying to improve the quality of education in response to the shortage; however, the effect of educational quality is not shown to be as fast as gender parity among STEM graduates or in organizational training. In Model 2, the relationship between quality of education and IT skills shortage is non-significant; this might be due to the mixed relationship between developing and developed countries since Model 2 represents more developing countries than Model 1. However, due to the sample size issue, in this study, the authors were not able to separate samples into two subgroups of developed and developing countries.

The hypotheses H2 is supported in both models. This empirically shows that the investment in organizational training can immediately help reduce the shortage of IT skills. However, it does not mean that business organizations should keep investing more and more in employee training. On the other hand, business organizations should work more closely with academic institutions in speeding up the readiness of IT graduates. Also, academic institutions can also reach out to the industry to better prepare the IT graduates. In addition, H3 is also supported in both Models 1 and 2. The better the country can attract and retain women in STEM field, the less the IT skills shortage. This does not mean that men are not important. But women, in general, are not interested in the IT field; being able to attract more women implies that there is more IT workforce in the country. Educators and policymakers have been trying to attract more women into STEM field (IT is part of STEM), and the empirical evidence from this study shows that the effort does pay off. Thus, improving strategies in attracting and retaining more women in to STEM field should be an on-going task for all stakeholders.

Contrary to H2 and H3, H4 is not supported in any of the two models. There is no relationship between technological infrastructure and IT skills shortage in both models. This result suggests that, in recent years (2014-2016), during which period countries tried to leverage the evolving digital economy by improving infrastructure and skilled workforce, technological infrastructure might have already been well established in the countries included in the analyses. However, to reduce the skills shortage, the results of the two models suggest that gender parity in STEM graduates and organizational training are the two critical factors that can quickly fix the skills shortage issue.

This study makes significant contributions to the global IT workforce literature in that it is the first study that empirically explores the relationships of important workforce development

factors and IT skills shortage at the country level. Also, objective measures of IT skills shortage are used, and this can overcome the issues that might arise from using the subjective ones, such as determining IT careers via a predetermined occupation code. For policymakers wanting to fix the IT skills shortage, the results revealed two critical factors that can quickly help in fixing the issue: gender parity in STEM graduate and organizational training. Of course, to have parity among STEM graduates, more women need to enroll in STEM fields, and this study provides substantial evidence supporting the research exploring how to attract women into IT and STEM fields.

The question of how to fix the IT skills shortage problem has been of scholarly interest since the mid-1980s. However, due to the limitation in the availability of data, no empirical quantitative study has been conducted to show the relationships between IT skills shortage and essential workforce development factors, including quantity and quality of education, organizational training, and gender parity among STEM graduates. To the authors' best knowledge, this study is one of the first. However, this is just the initial step in empirically investigating the factors related to the IT skills shortage, so there are quite a few limitations that future research could address. First is the sample size; more data should be available in the years to come, so if the sample size is more extensive, subsamples of developed and developing countries would be technically feasible. In addition to establishing subsamples, other analysis techniques such as structural equation modeling could be used to test the effect of the quality of education on the IT skills shortage when the sample size is large enough. Next, even though the measures used in this study seem to be the best available measures of the IT skills shortage, future research could still examine additional measures to capture the IT skills shortage of a country. Also, other factors that could potentially influence the IT skills shortage, such as policy, are worth examining as well if appropriate measures are available.

Although the authors have attempted an initial analysis of how the relationship between IT skills shortage and workforce development factors (quantity and quality of education, organizational training, and gender parity in STEM graduate) exist, their access to more IT-focused data is limited. The authors hope that this will present an opportunity for future research to determine the relationships between factors such as IT training in organizations, IT education, gender parity among IT graduates, and the IT skills shortage. The authors also hope that this initial evidence of how organizational training and gender parity among STEM graduates relate to countries' IT skill shortage can somewhat guide countries wanting to fix the IT skills shortage issue and entice research on IT workforce development.

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Appendices

Appendix 1. Variables and Measures

Variable	Measure and Description	Source
Dependent Variables:		
IT Talent Shortage	CIOs' perspective on IT talent shortage Percentage of CIO in a country reported that technology skills are hard to fill	CIO Survey by Harvey Nash / KPMG
	Managers' and Recruiters' Perspective on IT talent shortage IT skills ranking in the top ten hardest skills to find (0 – 10 (hardest to find, reversed the original value in the survey)	Talent Shortage Survey by Manpower Group
Independent Variables:		
Enrolment Percentage – Secondary and Tertiary	Quantity of education captures enrolment in secondary and tertiary education. Quantity of Education score is used, and it is an average score of two indicators below. Scale was converted to 1-7 using Min-Max Transformation • Secondary education enrolment, gross % • Tertiary education enrolment, gross %	WEF's Global Competitiveness dataset
Quality of Education	Quality of education captures quality of higher education, such as management schools, math and science, and the use of Internet in school for learning purpose. Quality of Education score is used, and it is an average score of four indicators below. Scale was converted to 1-7 using Min-Max Transformation • Quality of the education system, 1-7 (best) • Quality of math and science education, 1-7 (best) • Quality of management schools, 1-7 (best) • Internet access in schools, 1-7 (best)	WEF's Global Competitiveness dataset
Training	Training capture the extent to which companies invest in training and employee development. The score of the Extent of staff training indicator is used as a measure, with the scale 1 – 7 (best).	WEF's Networked Readiness dataset
Gender Parity in IT	Gender Parity in IT captures how representative is female in IT field. The ratio of female/male STEM graduate is used as a measure.	WEF's Gender Gap Index
Technological Infrastructure	Technological infrastructure captures the use of information technology at firm- and individual-level. An average score (scale of 1 – 7, best) of the following seven indicators is used in the analysis. • Availability of latest technologies, 1-7 (best) • Firm-level technology absorption, 1-7 (best) • FDI and technology transfer, 1-7 (best) • Individuals using Internet, % • Fixed broadband Internet subscriptions/100 pop. • International Internet bandwidth, kb/s per user • Mobile broadband subscriptions/100 pop.	WEF's Global Competitiveness dataset
Control Variable:		
Income	Income capture the average purchasing power of people in a country. Gross domestic product valued at purchasing power parity in billions of international dollars GDP (PPP$ billions) is used as a measure.	WEF's Global Competitiveness dataset Also available at the International Monetary Fund, World Economic Outlook Database

Appendix 2. Countries Included in Each Analysis

Model 1		Model 2	
Country*	**Time Point**	**Country***	**Time Point**
Australia	3	Argentina	2
Austria	1	**Australia**	3
Belgium	3	**Austria**	3
Canada	2	**Belgium**	3
Chile	1	Brazil	2
Finland	3	Bulgaria	2
France	3	**Canada**	3
Germany	3	Colombia	2
Greece	1	Costa Rica	2
India	1	Czech Republic	2
Ireland	3	**Finland**	3
Italy	2	**France**	3
Japan	1	**Germany**	3
Luxembourg	1	**Greece**	2
Mexico	1	Guatemala	2
Netherlands	3	Hungary	3
New Zealand	1	**India**	1
Norway	3	**Ireland**	2
Panama	1	Israel	2
Poland	3	**Italy**	3
Singapore	1	Japan	2
Spain	1	**Mexico**	2
Sweden	3	**Netherlands**	2
Switzerland	3	**New Zealand**	3
United Arab Emirates	1	**Norway**	2
United Kingdom	3	**Panama**	2
United States	3	**Poland**	3
Vietnam	2	Portugal	3
		Romania	2
		Singapore	1
		Slovak Republic	2
		Slovenia	2
		South Africa	2
		Spain	2
		Sweden	3
		Switzerland	3
		Turkey	2
		United Kingdom	3
		United States	3

Note. * Countries in bold are included in both models.

Appendix 3. Model 1's Correlation and Descriptive Statistics - CIOs' Perspective on IT Skills Shortage

Variable	ITSS	GPD	EPST	Edu_Qual	TRA	GP	TI
IT Skills Shortage (ITSS)	1.00						
GDP (PPP$ billions) (GDP)	-0.01	1.00					
Enrolment Percentage in Secondary and Tertiary Education (EPST)	-0.48	0.09	1.00				
Quality of Education (Edu_Qual)	-0.18	-0.04	0.38	1.00			
Training (TRA)	-0.16	0.03	0.21	0.82	1.00		
Gender Parity in STEM Graduates (GP)	0.01	0.09	-0.31	-0.35	-0.47	1.00	
Technological Infrastructure (TI)	-0.27	-0.03	0.55	0.76	0.71	-0.43	1.00

Variable	Obs	Mean	Std. Dev.	Min	Max		
IT Skills Shortage (ITSS)	57	0.64	0.11	0.39	0.86		
GDP (PPP$ billions) (GDP)	57	2042.75	3783.88	55.73	17947.00		
Enrolment Percentage in Secondary and Tertiary Education (EPST)	57	6.17	0.86	3.34	7.00		
Quality of Education (Edu_Qual)	57	5.10	0.67	3.53	6.13		
Training (TRA)	57	4.80	0.61	3.19	5.71		
Gender Parity in STEM Graduates (GP)	57	0.39	0.13	0.18	0.82		
Technological Infrastructure (TI)	57	5.60	0.77	2.99	6.41		

Appendix 4. Model 2's Correlation and Descriptive Statistics – Managers' and Recruiters' Perspective on IT Skills Shortage

Variable	ITSS	GDP	EPST	Edu_Qual	TRA	GP	TI
IT Skills Shortage (ITSS)	1.00						
GDP (PPP$ billions) (GDP)	0.13	1.00					
Enrolment Percentage in Secondary and Tertiary Education (EPST)	0.17	0.09	1.00				
Quality of Education (Edu_Qual)	0.39	0.08	0.48	1.00			
Training (TRA)	0.31	0.17	0.12	0.72	1.00		
Gender Parity in STEM Graduates (GP)	0.03	-0.04	-0.25	-0.40	-0.50	1.00	
Technological Infrastructure (TI)	0.28	0.10	0.58	0.85	0.66	-0.51	1.00

Variable	Obs	Mean	Std. Dev.	Min	Max
IT Skills Shortage (ITSS)	92	6.02	3.58	1.00	11.00
GDP (PPP$ billions) (GDP)	92	1551.99	3099.02	57.44	17947.00
Enrolment Percentage in Secondary and Tertiary Education (EPST)	92	6.11	0.86	2.82	7.00
Quality of Education (Edu_Qual)	92	4.72	0.80	3.11	6.13
Training (TRA)	92	4.48	0.68	3.19	5.71
Gender Parity in STEM Graduates (GP)	92	0.43	0.14	0.16	0.82
Technological Infrastructure (TI)	92	5.24	0.82	2.99	6.41