Technological Change and Labor Market Disruptions: evidence from the developing world

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ABSTRACT

Digital technologies are changing the world of work. They are shifting the skills a worker needs to success in "new economy" jobs. This technological change, together with globalization and urbanization, is likely to generate important labor market disruptions. It may generate them because it is skill-biased and labor saving. However, the evidence to date has been limited to advanced countries – mostly the U.S. We use novel data for developing world countries to assess the potential disruption to their labor market, to provide a typology on the extent of this disruption, and to classify the countries on their capacity of their skill development systems to adapt to this disruption.

EXTENDED ABSTRACT

Digital technologies are changing the world of work. The use of digital technologies, such as computers, mobile phones and the internet, are modifying, expanding and replacing specific tasks or even complete jobs. The main channel through which these digital technologies are shifting the world of work is by changing the skills that workers need to succeed in "new economy" jobs (Autor, Levy and Murnane 2003).

The evidence, so far limited to advanced countries– mostly the U.S. – on how technology affects the labor markets points to two forces. The first one is that technological change is skill biased (Acemoglu & Autor, 2011; Autor & Handel, 2013). Similarly to other waves of technological waves, digital technologies disproportionally increases the productivity of high-skilled workers. More specifically, the skill-biased nature of this technological change comes in form of a reduction in the demand for workers doing tasks that are mostly routine (those more likely to be computerized), while it increases the demand for workers doing tasks that are mostly non-routine. (Acemoglu, 2002; Autor, Katz, & Kearney, 2008; Autor D. H., 2014). This leads inevitably to the polarization of the labor market (Autor D. H., 2014; Autor & Dorn, 2013).

The second force is that this technological change is labor saving (D. H. Autor 2014). In this case, occupations with a substantial number of tasks that are routine can be fully automated. This has been the case, for example, of many travel agents (Frey & Osborne, 2013; Brynjolfsson & McAfee, 2014).

Through these forces, technological change, together with globalization and urbanization, is likely to generate important disruptions in the labor market. Yet the evidence to date is limited to advanced economies (for instance, Krueger, 1993; DiNardo & Pischke, 1997; Spitz-Oener, 2006; Handel, 2007). There is little evidence on how technological change has affected the labor market in the developing world. This is the gap that this paper seeks to fill. Using novel data from the Skill Towards Employment and Productivity (STEP) surveys in 10 countries and 1 Chinese province, and expanding it to around 30 developing world countries, we address this gap in three ways:

1. *We measure the extent of use of digital technologies at work and, how this correlates with changes skill requirements for a set of developing world countries*. In order to measure the

extent of use of digital technology at work, we build an index of ICT intensity. The index contains information about computer frequency and complexity of use, as well as use of digital technologies such as internet and mobile phones. We later use the average index at an occupation level to extrapolate to other countries and discuss the correlations with the changes in skill requirements.

2. *We measure the extent to which the risk of automation, as estimated by Frey & Osborne (2013), can affect labor markets.* The risk of automation was estimated by Frey and Osborne (2013) for the U.S. We extrapolate the information of the probability of being automated to the same data sets we used to estimate the index of use of digital technology. We do this at an occupation level. This gives us information on the magnitude and characteristics of the jobs that are in high risk of being automated based on the technological feasibility of such automation. We take it a step beyond to adjust for the fact that are adopted and diffused with a time lag in the developing world. To adjust for this, we use information from Comin and Hobijn (2010) on the adoption lags of 20th century technologies.
3. *We put together our estimates of use of digital technologies at work with those for the risk of automation to build a more complete picture of the extent of the labor market disruption that developing countries can face as a result of these forces.* The goal of putting together the estimates of use of digital technology at work with those of automation is to build a typology of countries based on the relative degree of labor market disruption of these two forces. Similarly, we classify countries according to their capacity to respond and adapt to technological changes in the labor market, mostly determined by their quality of their skill development systems.

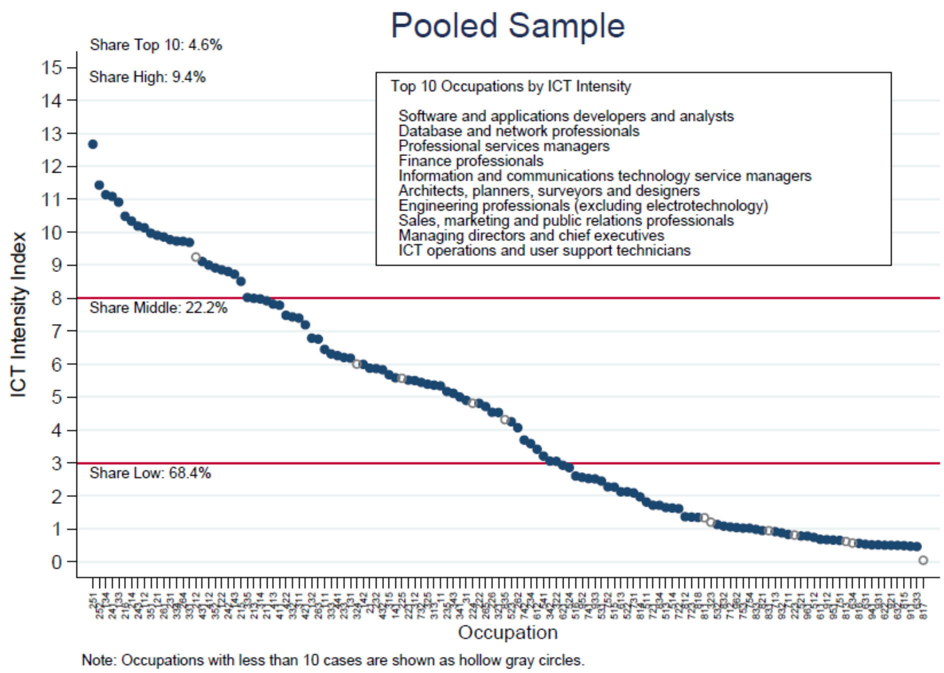
1. Introduction

2. Literature Review

3. Measuring the use of digital technologies at work

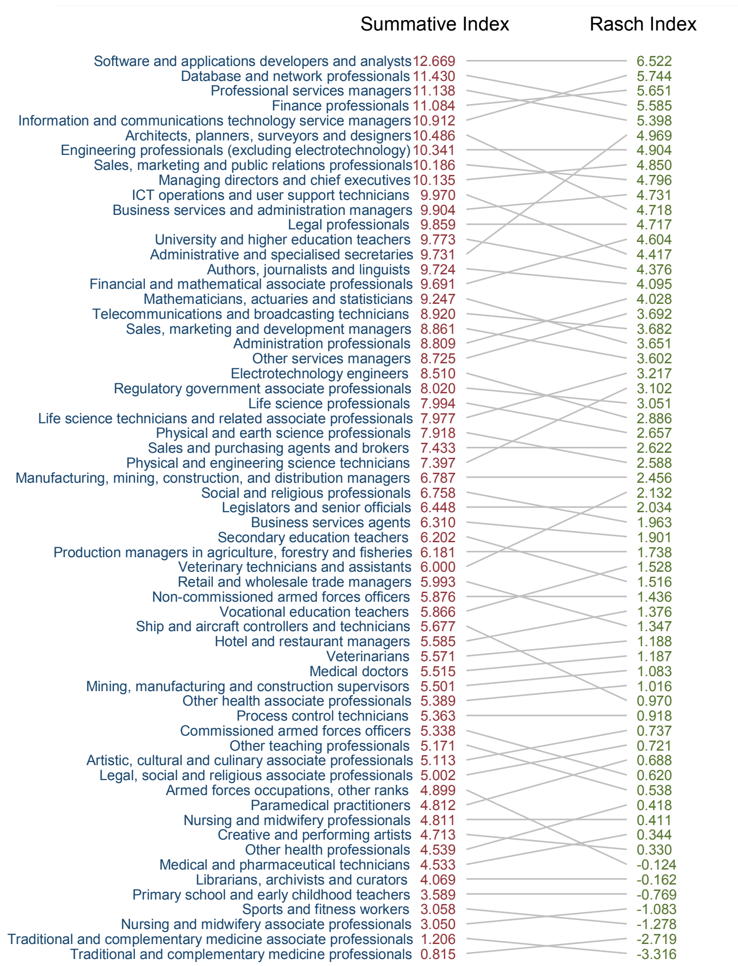
- Index constructed using STEP surveys.
  - What are the STEP surveys?
    - This paper uses the STEP surveys from one province in China (Yunnan) and ten countries: Armenia, Bolivia, Colombia, Georgia, Ghana, Kenya, Lao PDR, Macedonia, Sri Lanka, and Vietnam. These surveys contain comparable information on cognitive skills, socio-emotional skills and the use of job-related tasks use. In addition to the skills measures described above, the surveys gather extensive information on education and employment outcomes, and individual and household characteristics.
  - What were the inputs for the index?
    - STEP includes in the employment module a block of questions aimed to measure the use of ICT technologies for everyday work activities. Several questions of those questions were selected to assemble the ICT index (the details are reported in the Appendix). Questions included in the index are self-reports of the use of mobile phones and computers at work, a measure of frequency of use of computers at work, and the requirement to use to perform certain activities (such as emailing, data entry, word processing) and the use of different type of some software tools (spreadsheet, word processors, presentation).
  - How was the index constructed?
    - The index is a summative measure based on a set of items/components. The items are derived from responses to several questions in the survey to the population currently employed. Except for a question that measures the frequency of use, most of the responses are transformed into binary indicator (0/1) to represent the absence/presence of each trait.
    - Index is estimated separately per country using survey weighting to expand results for the full sample. Indices per country are then aggregated to obtain the pooled sample index. No weighting scheme is used in this step.
    - The pooled index only includes the urban subset of country level samples; hence Yunnan Province in China (not a country), Sri-Lanka and Lao PDR samples are excluded. Also, due to lack of consistent data at occupation level, data from Ukraine is excluded from the pooled sample estimation.
    - In theory, the index can assume values ranging from 0 to 19, but the spare use of ICTs at work tend to concentrate responses around the zero value.
    - The observed mean of the index for the pooled sample is 3.498.
    - To address the validity in the process of constructing the index we explore the ranking of occupations. The rank of occupations based on a 3-digit level ISCO-08

classification is consistent with level of ICT intensity expected (ref: graph, Pooled Sample)



Source: Step surveys

- Does the estimation procedure matter?
  - A summative index assumes that each component weights equal. An alternative assumption is to weight each item differently by using and IRT model.
  - We re-assemble the index using a Rasch model to capture differences in the probability of responding to some components. Overall, the IRT version of the index behaves in a similar manner to the summative index.
  - Ordering among most of the occupations is preserved: Pearson: .968, Spearman: .999. (ref rank plot of professionals and technicians).
  - Further inspection for occupations with high skill demands shows that some reordering occurs; most occupations retain their positions within the ranking.
  - Because it is a parsimonious solution, we decided to retain the simple summative index.



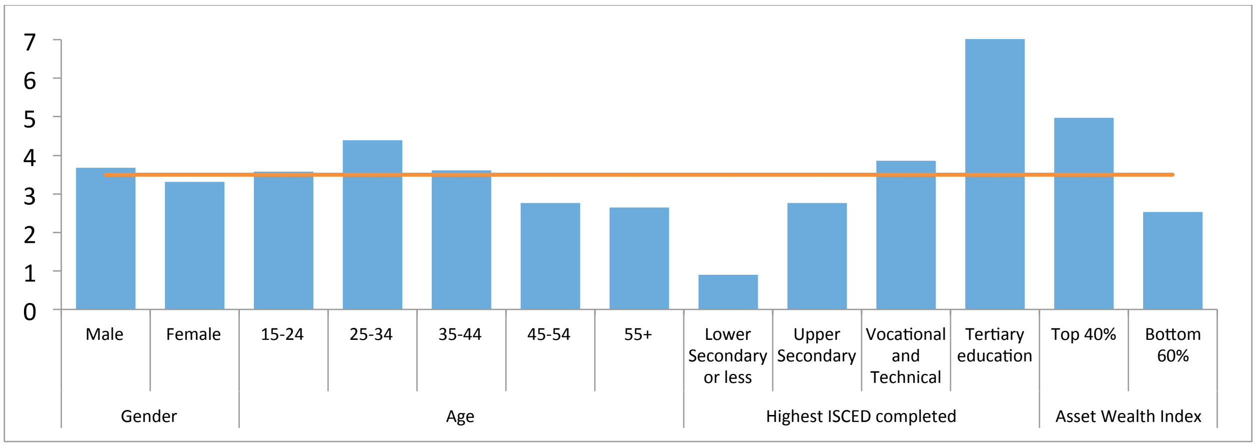
Source: STEP surveys

- Evidence from developing world
  - Descriptive analysis.
    - In a sample of developing countries, the ICT intensity index exhibits a low value: the mean value of the index is 3.498 in a range of 0-19. This value is driven, in large part, by the high proportion of the employed population who do not actively used ICT in their everyday jobs.
    - Differences are observed among some subgroups. The use of ICT is slightly intensity among males than females. Based on the age of respondents, a U-shaped relationship is observed but some caution should be observed given the low share of the 15-24 among the employed population.
    - As expected, the intensity of used increases with education, with the higher education holders, with an index value two-fold the value observed in the closest education level.
    - The employed population in the wealthier group (top 40% of the assets wealth index) shows an intensive ICT in comparison with those in the bottom group.
    - On average, the mean value of the index observed by occupational group at 1 digit shows a clear divide. On one side, the white collar occupations including

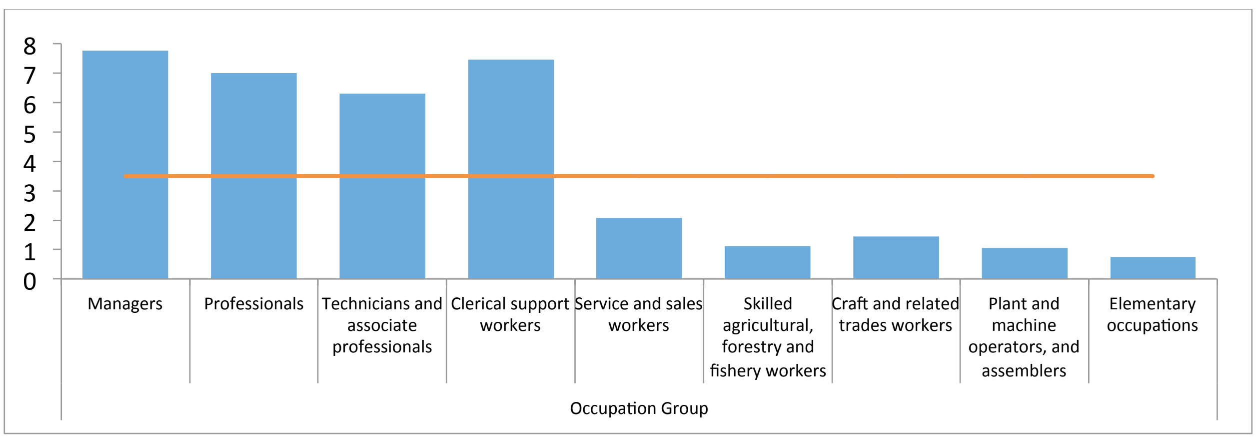
managers, professionals, technicians and clerical workers have an intense use of ICT with a mean score value of 6 and over. In the other extreme, blue collar occupations show a low use of ICT (score less than 2).

- The differences for the pooled sample hold when each country is analyzed separately.

Graphs: Mean value of ICT Intensity Index by selected characteristics

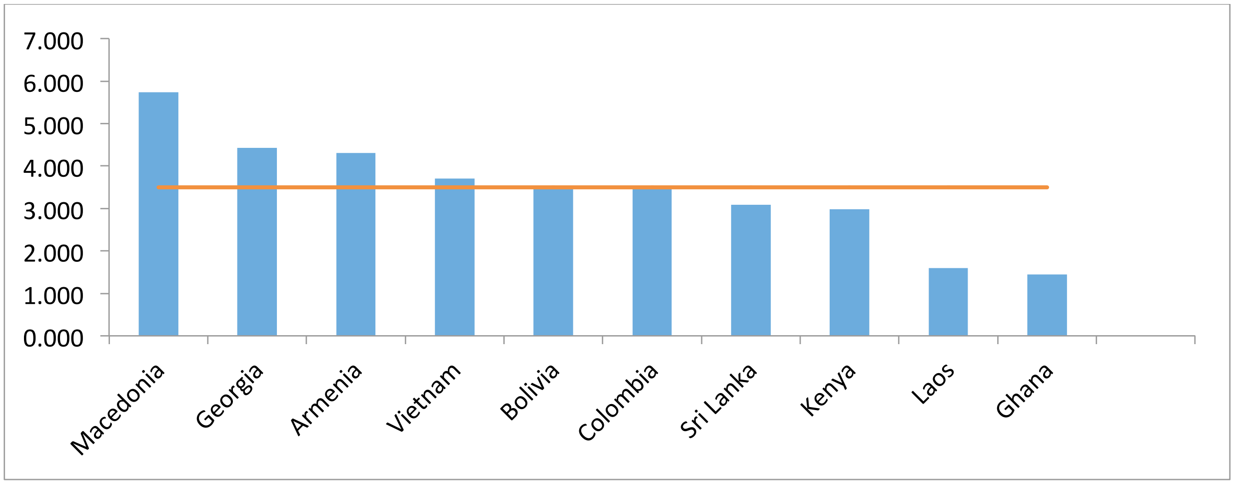


Source: STEP surveys



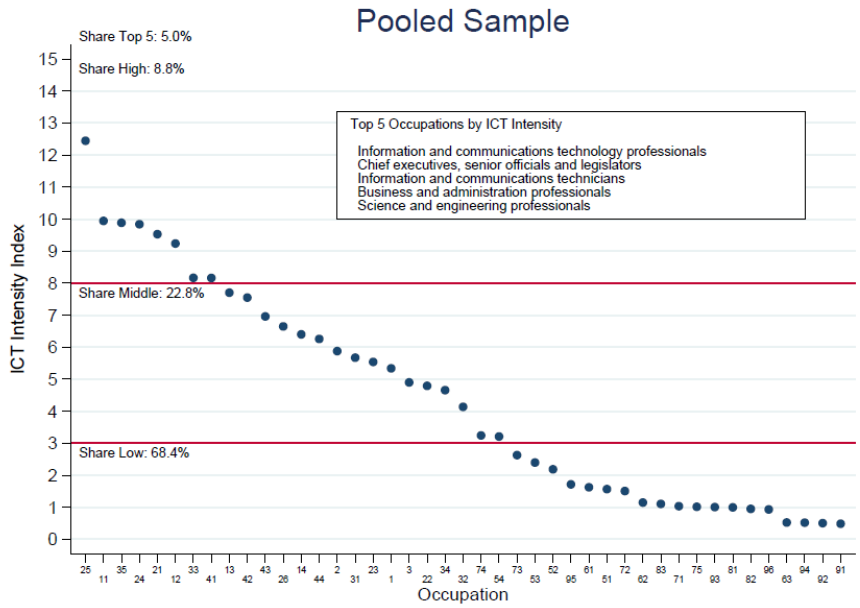
Source: STEP surveys

- Ordering of countries according the mean index value places Macedonia at the top of the list, and Lao PDR and Ghana at the lowest extreme.
- As it was indicated previously, the sample corresponding to Yunnan Province was not included for the estimation of the Pooled Sample index. However, if we took the aggregated mean score for this territory and compare it with the countries included in the pooled sample, Yunnan would have ranked right after Macedonia. Similar exercise with Ukraine would have ranked it after but close to Armenia.



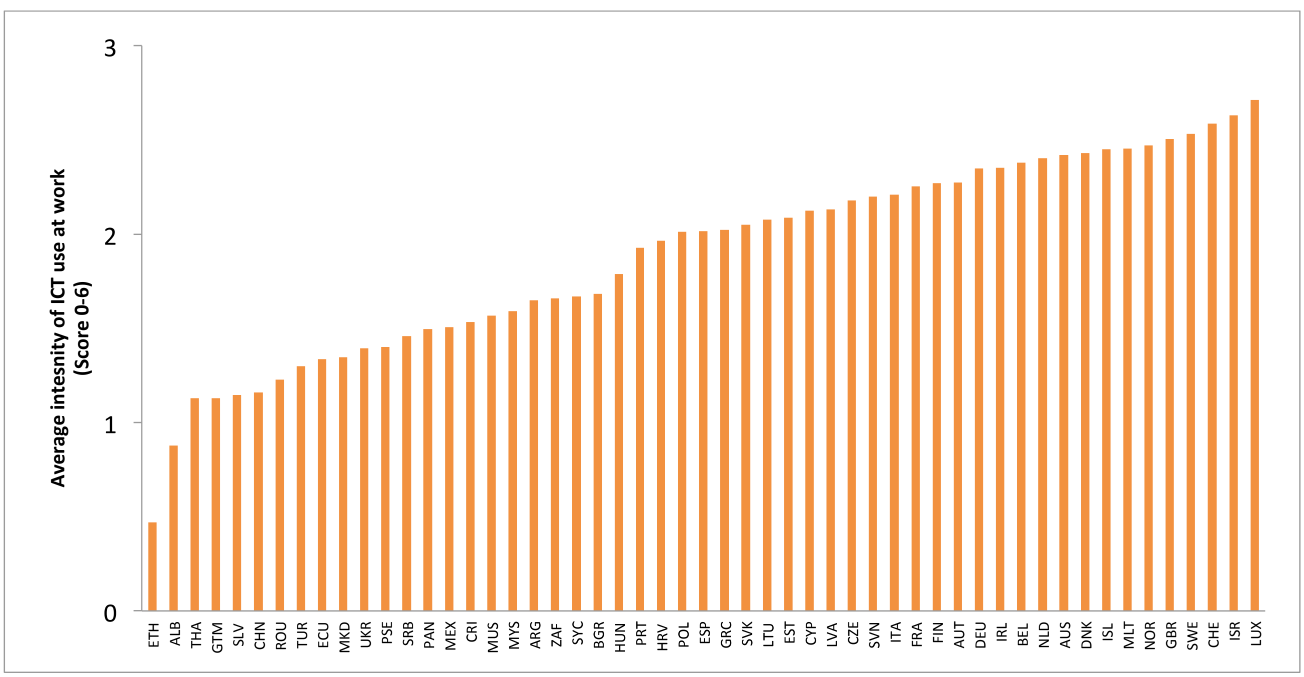
Source: STEP surveys

- The index can be expanded to other countries.
  - Data availability represents a problem in some countries. Not always is possible to obtain micro-data coded at detailed levels for occupations (3 digits or more). In many countries, the data is even coded using national variations of ILO-ISCO.
  - To extend this analysis to more countries an alternative is to aggregate the results of the index at 2 digits taking advantage of the hierarchical nature of the ISCO-08 scheme. Then, secondary data sources of other countries with occupations coded at 2-digit level using ISCO-08 (or 88 via a crosswalk). Using STEP, a 2-digit aggregation preserved the order of occupations with the ICT-related group of occupations ranking in the top position.



Source: STEP surveys

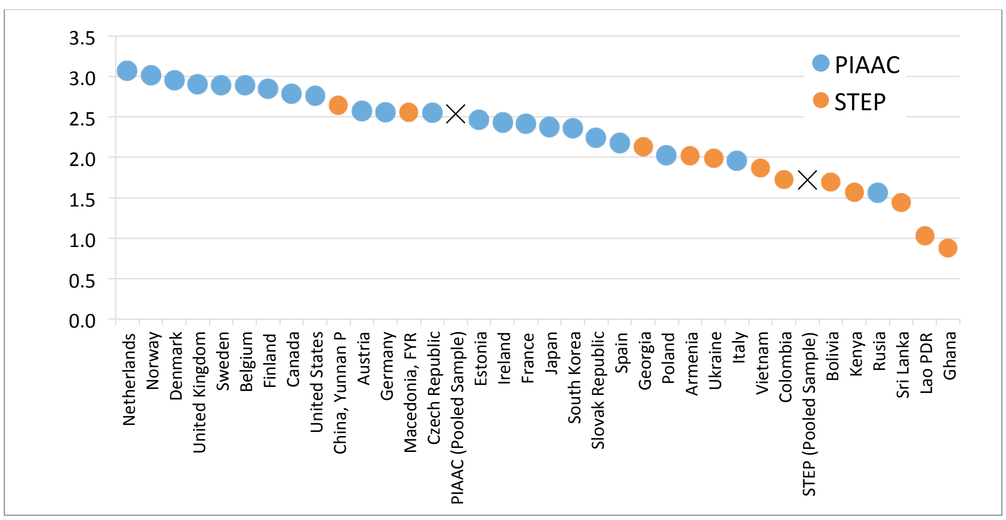
- A similar exercise is performed extrapolating the ICT index to more countries using ILO Laborsta data with ISCO 08 codes at 2 digits.
- The sorting of countries is as one could expect. Lower income countries tend to use less, on average, ICT at work less intensively.



Source. ILO Laborsta.

- Given that STEP is a survey aimed to developing countries; the ICT intensity index is able to capture the intensity of use based on the patterns prevalent in these countries. If we aim to extend these findings to additional countries we also need to confirm that the variations in the use of ICT varies by type of economy (low vs high income), do not affect the index values.
- We devise a method to assemble a comparable ICT intensity index based on information from different type of economies. For that matter, we use the PIAAC survey. This is a survey conducted in many OECD economies which includes a module about ICT use at work, and a set of similar questions to the ones available in STEP. Common questions were identified and used to assemble a new version of the ICT index comparable for STEP and PIAAC. Further analysis was conducted to assure the comparability between both indices.
- The order of the countries using a comparable ICT intensity index the block of advanced economies included in PIAAC rank higher than their countries counterparts in STEP. Except for Macedonia and the Province of Yunnan in China, and Russia the order observed is consistent with the level of development of the countries included in each of the samples. Other relevant trait is that the variation of the index among countries that participated in PIAAC is smoother than the variation observed among participant countries in STEP.

Average ICT Intensity Index (comparable version) by survey sample

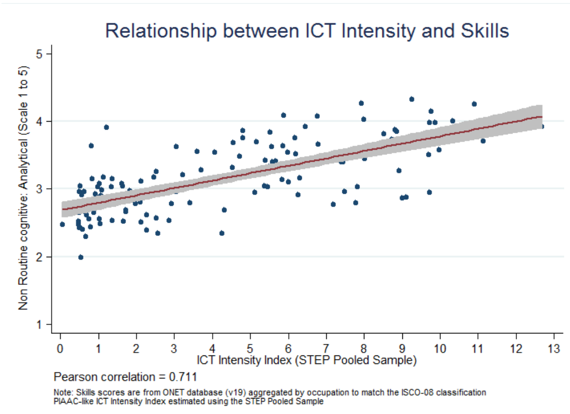


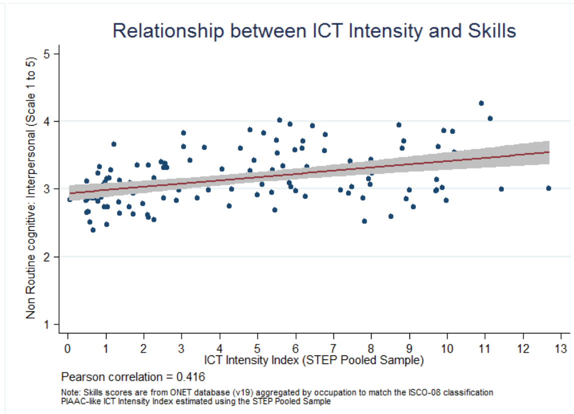
Source: STEP and PIAAC surveys

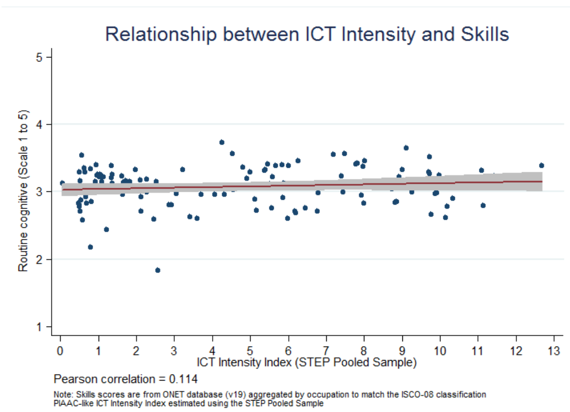
4. Linking the use digital technologies at work with changing skill needs.

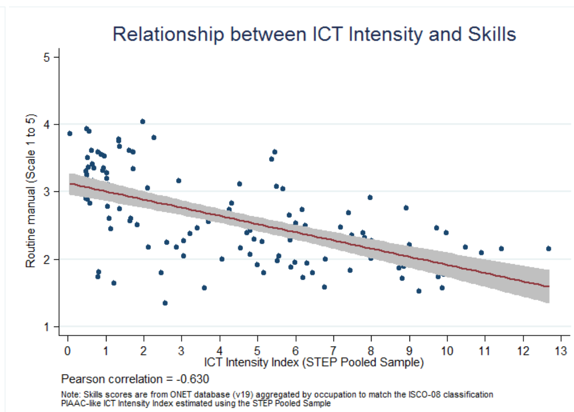
- Skills scores are composite measures built based on (Acemoglu and Autor 2011). Scores at detailed occupation level are extracted and assembled from the ONET v19 database. Scores are aggregated to the SOC2010 level, then crosswalked with ISC08 at 4-digit level. Further simple aggregations at 3, 2 and 1 digits are performed.

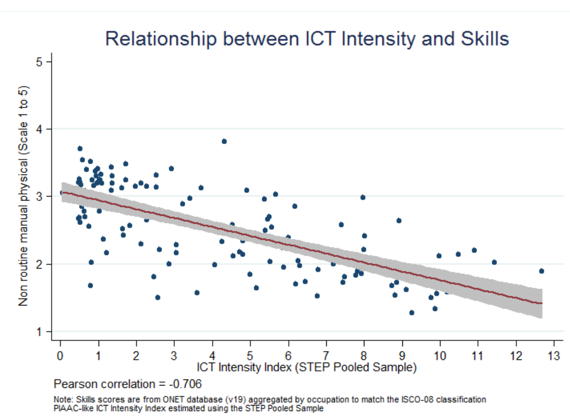
- Graphs show the correlation between the ICT Intensity Index estimated for the STEP Pooled Sample and skills scores at ISCO-08 3-digit occupation level.
- At occupation level, the ICT index exhibits a positive relationship with the cognitive analytical skill, and negative manual skills. Occupations intense in the use of ICT are more likely to be occupations with a high demand of cognitive skills and a spare use of routine and non-routine manual skills.







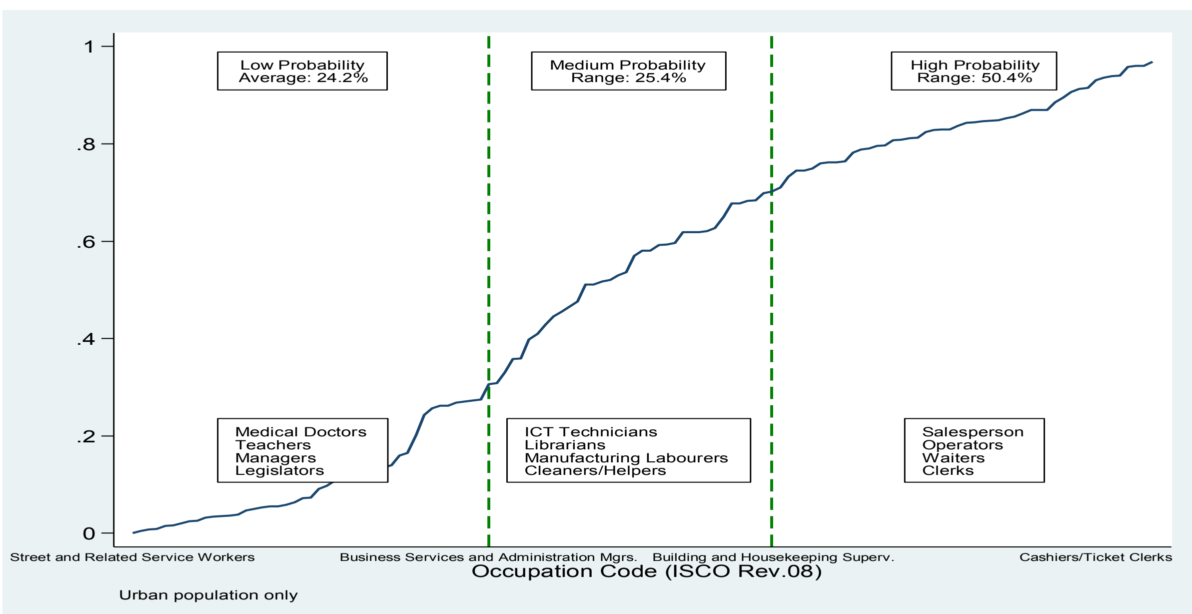




5. Potential risk of automation in the developing world.

Technological feasibility

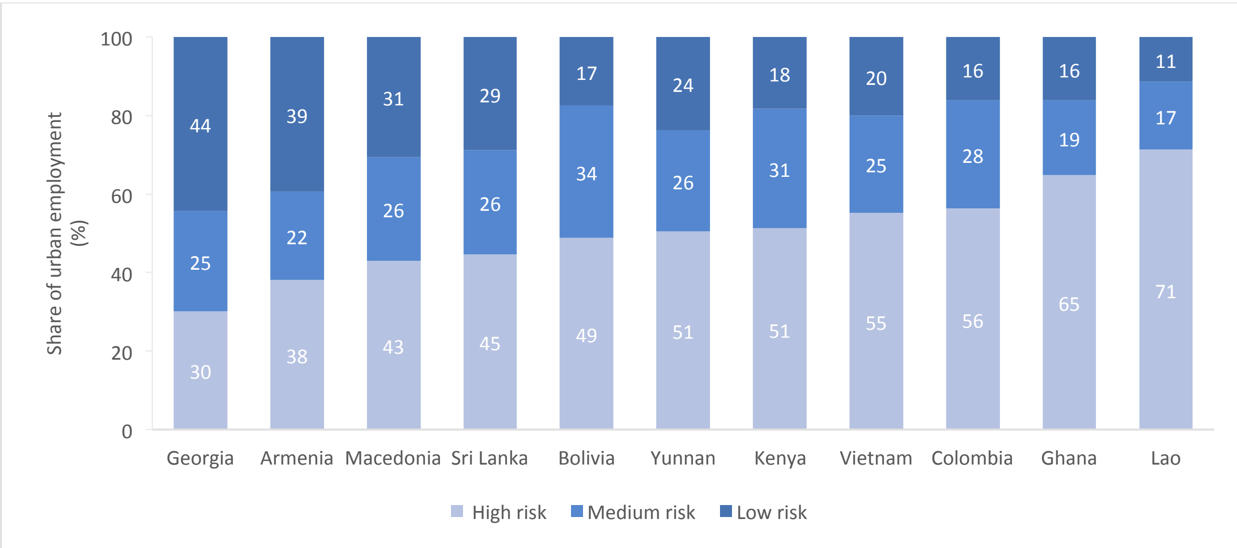
- Forward looking aspect ICT use at work and the change in skill needs.
- Frey & Osborne (2013) work.
    - Computerization: job automation by means of computer-controlled equipment.
    - More than automation, there is a role for computerization of tasks in jobs. The more tasks can be computerized in a job, the more likely a job will be fully automated.
    - Change from SOC to ISCO in the US
- Technology stand point.
    - "Rather we aim, from a technological capabilities point of view, to determine which problems engineers need to solve for specific occupations to be automated" (Frey and Osborne 2013, 4)
    - The ranges to determine the risk level of computerization are:
        - Low: less than 0.3
        - Medium: 0.3 to 0.7
        - High: more than 0.7.
    - The employment shares for 2013 for the US: low risk 26%, medium risk 33% and high risk 41%, using ISCO 08 at 3 digit. This are slightly different from the SOC presented in Frey and Osborne (33%, 19%, and 47%) due to aggregation to a higher level within ISCO, because when using ISCO 08 at 4 digit, the shares are 32, 20 and 48 respectively.
    - The order of occupations still makes sense. For instance, medical doctors, teachers and managers have a low probability of being computerized, while salesperson, operators and ticket clerks have high probability of being automated. This ordering is fairly consistent to the one presented by Frey and Osborne (2013) using the SOC codes.



Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

- How do the risk of computerization play out in the developing world using STEP countries?

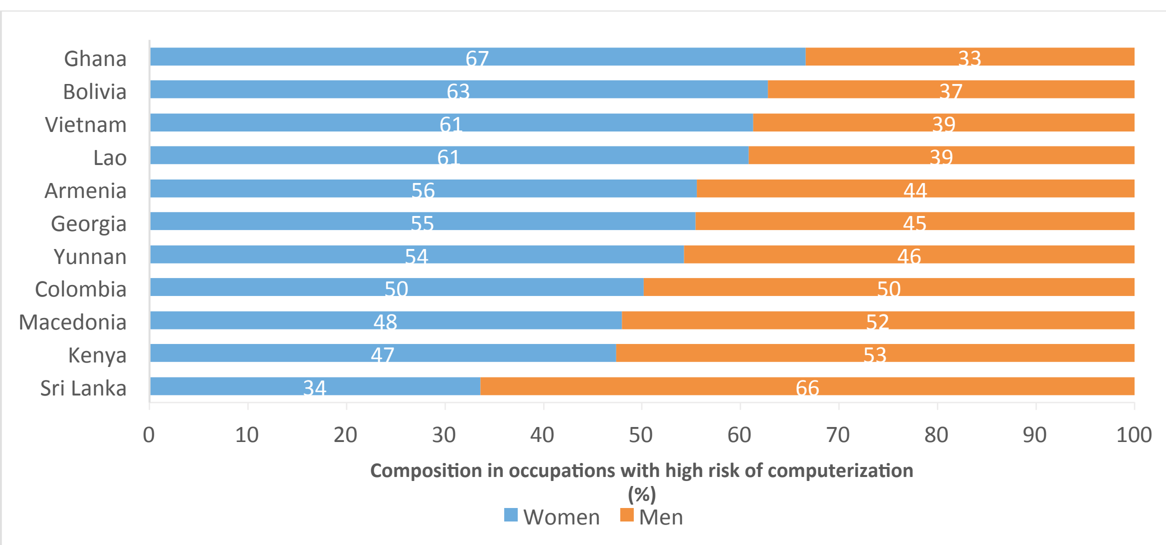
- Poorer countries would face a grimmer panorama on the share of employment that can face computerization, only from a technology stand point.
- This is because most of the employment in the poorer countries are mostly in routine occupations.



Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

Who are the ones affected in these countries?

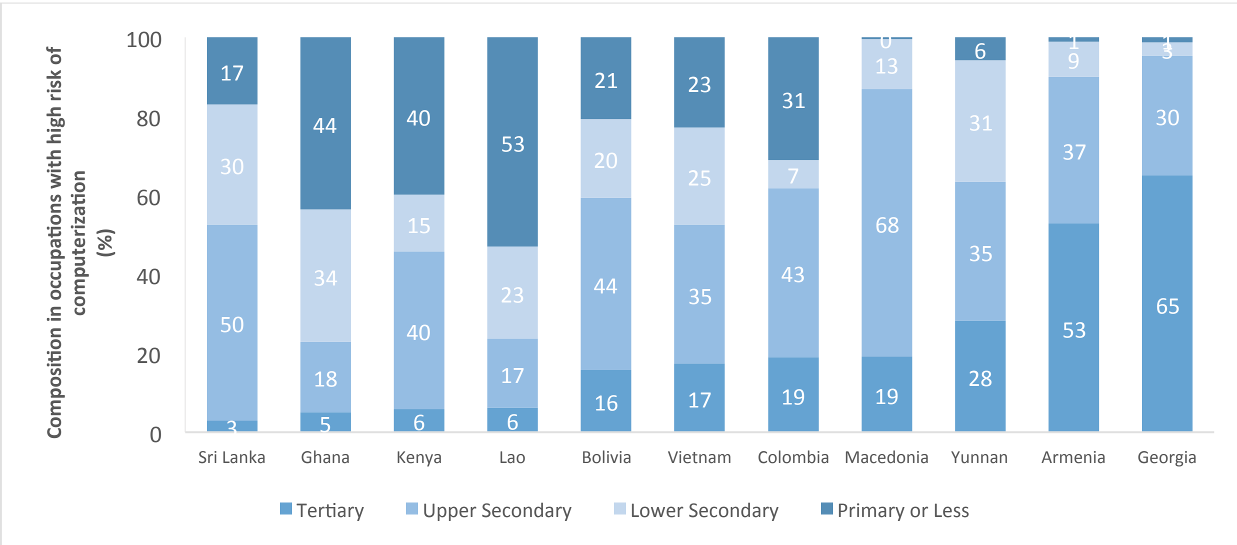
- The gender composition in the occupations with high risk of computerization, is on average equally distributed.
- However, there is large heterogeneity across countries, ranging from a 34% of women in Sri Lanka, to a 67% in Ghana.



Source: STEP surveys.

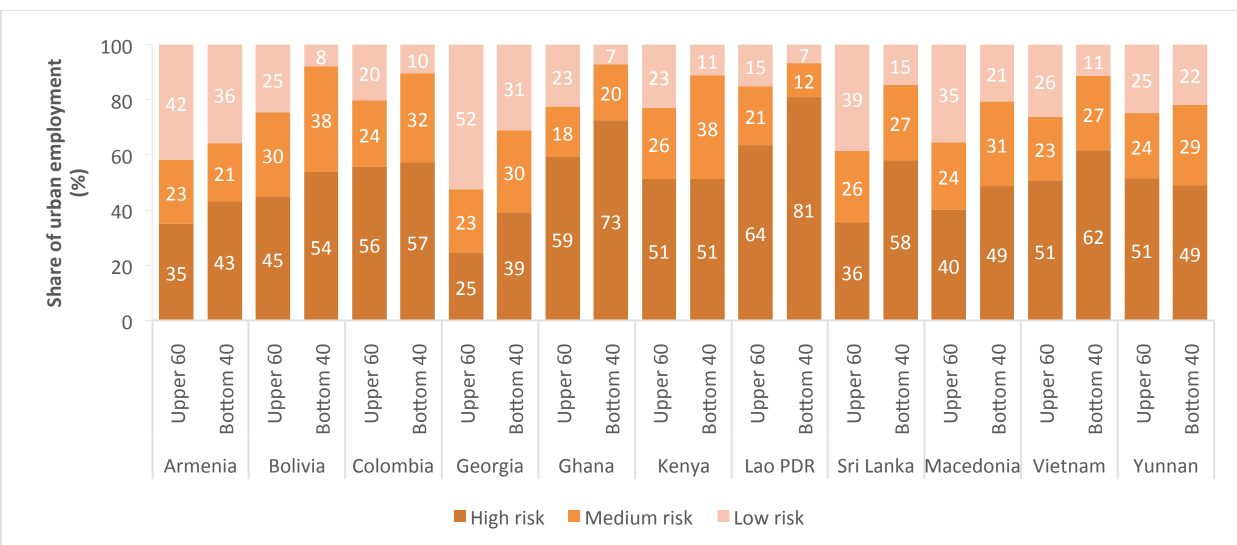
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

- In most countries, except Armenia and Georgia, there is between a 70 to a 97 percent of the employed population in occupations with high risk of computerization with an educational attainment of secondary or less.



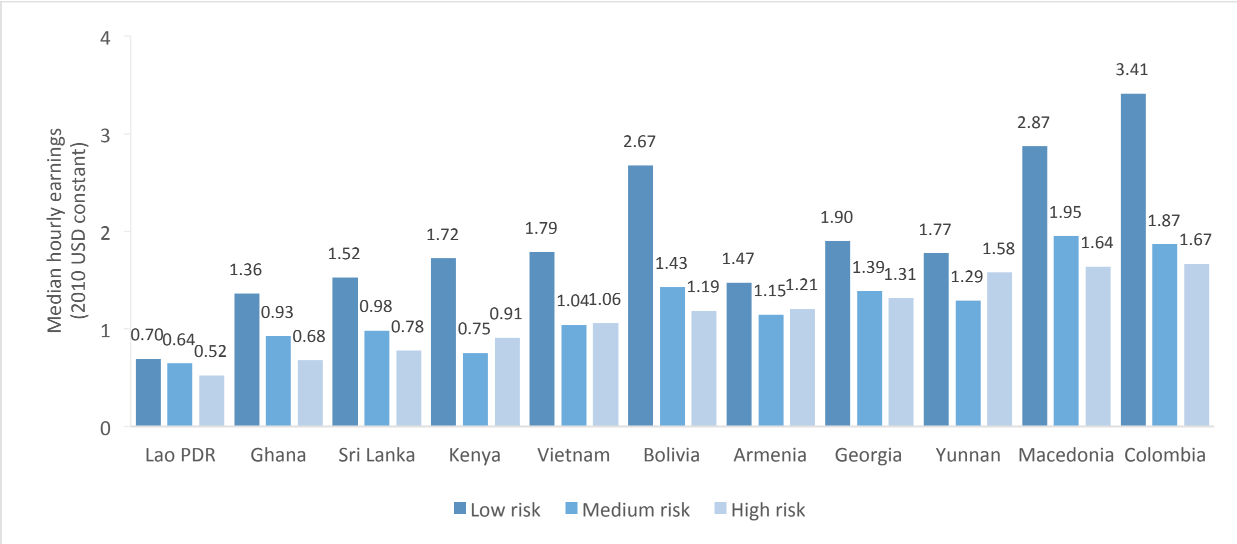
Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

- Those in the bottom 40 of the distribution are more likely to be on occupations with high risk of computerization. They share of bottom 40 workers in urban areas for these countries go from 40 percent in Georgia to 81 percent in Lao PDR.



Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

- The gap of in the median hourly earnings (2010 US constant) between those in occupations with low risk of computerization and those in high risk is on average 78 cents across these countries.
- They can go from around 17 cents in Lao PDR to $1.75 in Colombia.



Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

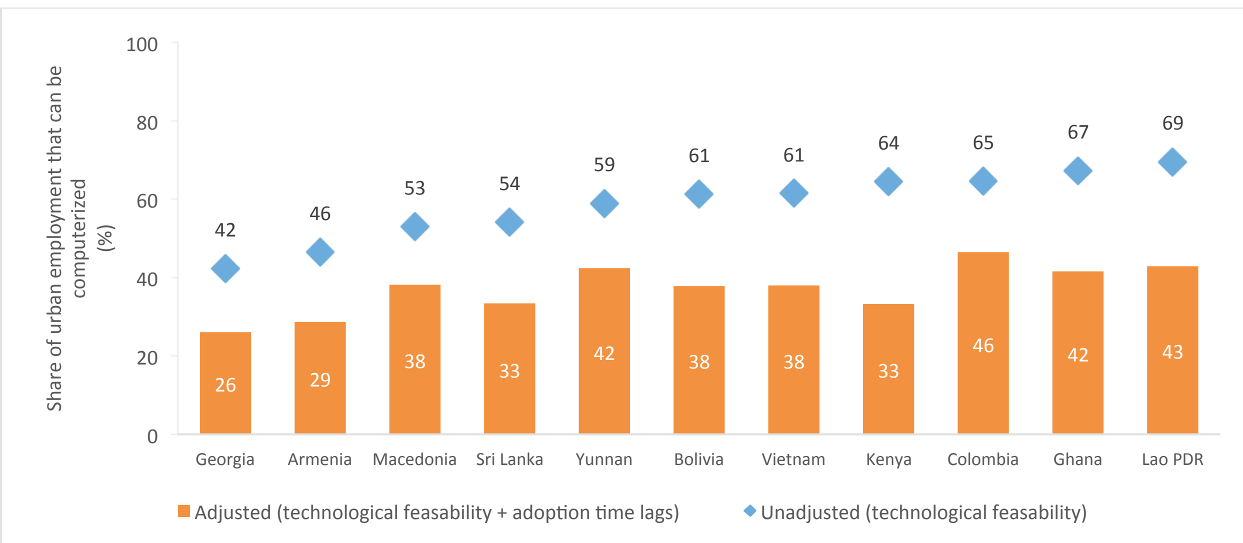
Taking into account the adoption lags

- The time frame of Frey and Osborne in these changes to happen is around 2 to 3 decades.
- However, the technology will not be immediately adopted in the developing world. There will be a time lag between the invention and the technology being introduced in a given country.
- One would ideally want to control for lag in adoption and diffusion of such technologies. There is no information about the diffusion, so we use Comin and Hobijn (2010) adoption time lags. Thus, our estimates will become a lower bound estimation.
- This should not matter because we are more interested in the relative position between countries: rich countries are more of early adopters while poorer countries are late adopters.
- One of the main results from Comin and Hobijn (2010) suggest that adoption lags are large, with substantial variation across countries and technologies. Newer technologies have been adopted faster than older ones. (p. 2033).
- We took only into account technologies in the 20th century, from the ones listed in Table 2 (Comin and Hobjin (2010) p. 2048).

Technology	**Invention Year**	**Adoption Lags**		
		10%	**50%**	**90%**
Aviation – passengers	1903	21	29	53
Aviation – freight	1903	24	42	61
Cell phones	1973	10	16	19
PCs	1973	10	14	17
Internet users	1983	5	8	11

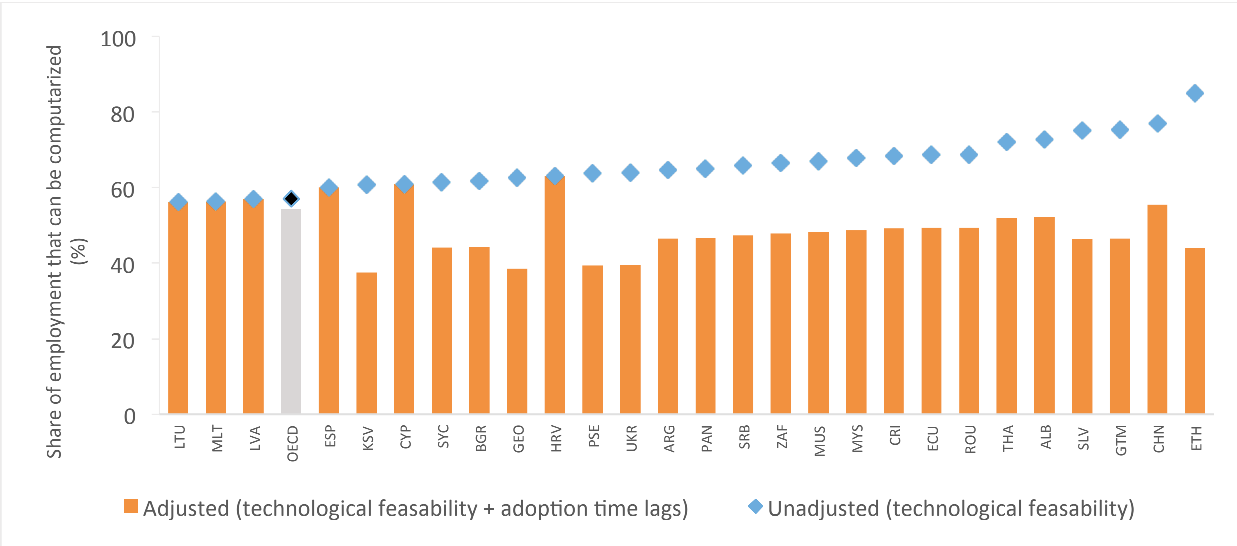
MRIs	1977	3	5	7
Blast oxygen steel	1950	9	16	28
Average Adoption Lag		**11.71**	**18.57**	**28**
Source: Comin and Hobjin (2010) p. 2048				

- We assume that the developed world will take 30 years to adopt the necessary technologies to realize the risk of computerization in their labor market. We also, assume that the upper middle income countries are the next in line to adopt, thus they are part of the first 10%; lower middle income countries are in the 50% of the adoption lags; and, the low income are in the 90%.
- In other words, for automation to take place in a lower middle income country, we are assuming that it will take 48.57 years (the 30 years of the benchmark – high income countries- plus 18.57 years).
- We use this information to adjust the share of employment that can be computerized in a given country.
- For instance, in the urban Bolivia, the unadjusted share of employment that can be computerized is 61%. Bolivia is a low middle income, so the average adoption lag is 18.57. So, adjusting for the adoption time lag, the share of employment that can be computerized is 38%.



Source: STEP surveys.
Note: Urban employment only. The probability was imputed per occupation at a 3 digit level (ISCO 08).

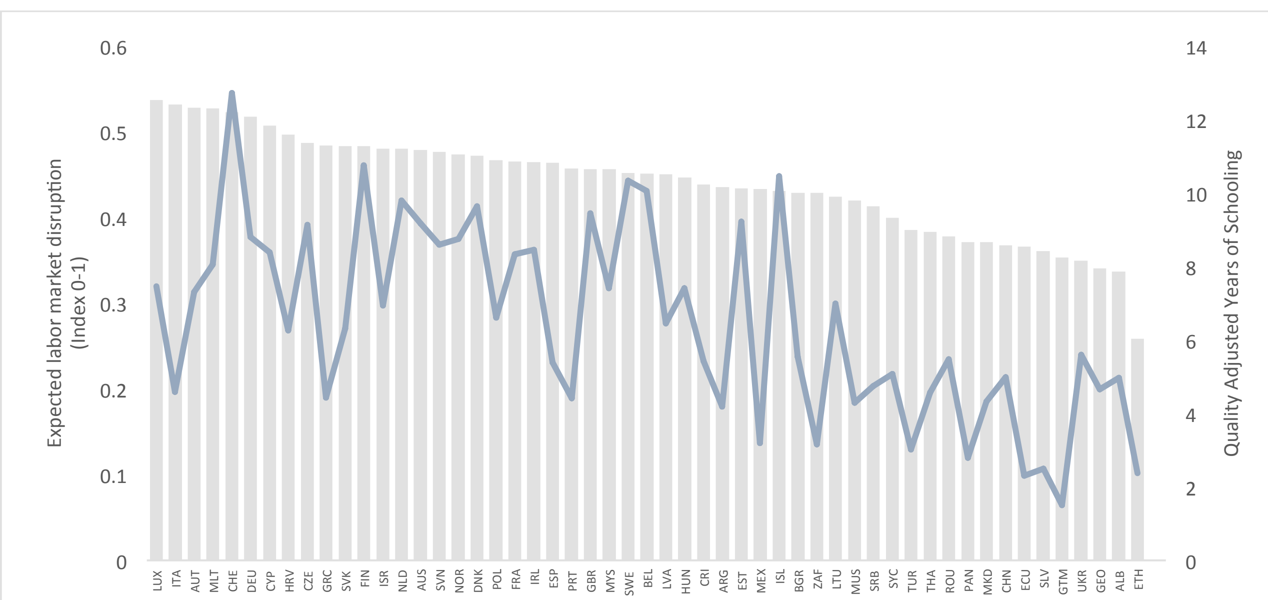
- How does this affect the rest of the developing world?
- We use the ILO data that contains information of the employment share by ISCO 08 occupations at 2 digit level of aggregation. We aggregated and imputed the probability at this 2 digit level.



Source: ILO laborsta.
Note: Total employment. Occupations aggregated at 2 digit level.

6. The link between the use of technologies at work and automation, with labor market disruptions.

- Index of labor market disruption.
  - Standardized summation
  - Rescaling
  - Quality adjusted years of education
- Evidence from the developing world.



Source: ILO laborsta. Barro and Lee. World Economic Forum.
Note: Total employment. Occupations aggregated at 2 digit level.

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Appendix

Table: STEP questions used to assemble the ICT Index

Question	Round 1	Round 2	Responses	Values
As part of this work do you (did you) regularly use.... A TELEPHONE, MOBILE PHONE, PAGER OR OTHER COMMUNICATION DEVICE?	m5b_q13_1	m5b_q15_1	1 Yes	1
			2 No	0
As a part of your work do you (did you) use a computer?	m5b_q16	m5b_q18	1 Yes	
			2 No	0
How often do you (did you) use a computer at work?	m5b_q17	m5b_q19	1 Every day	4
			2 Three times or more per week	3
			3 Less than three times per week	2
			4 Almost never	1
Does (did) your work as [OCCUPATION] require the use of the following?	m5b_q18_1	m5b_q20_1	Email	1
	m5b_q18_2	m5b_q20_2	Searching for information on the internet	1
	m5b_q18_3	m5b_q20_3	Data entry	1
	m5b_q18_4	m5b_q20_4	Word processing (such as word)	1
	m5b_q18_5	m5b_q20_5	Spreadsheets (such as excel)	1
	m5b_q18_6	m5b_q20_6	Databases (such as access)	1
Does (did) your work as [OCCUPATION] require the use of other software packages, OR designing websites, OR doing programming or managing networks?	m5b_q19	m5b_q21	1 Yes	
			2 No	
Does (did) your work as [OCCUPATION] require the use of?	m5b_q20_1	m5b_q22_1	Advanced functions in spreadsheets such as macros and complex equations	1
	m5b_q20_2	m5b_q22_2	Book-keeping, accounting or financial software	1
	m5b_q20_3	m5b_q22_3	Presentation, graphics software (such as powerpoint)	1
	m5b_q20_4	m5b_q22_4	Designing websites	1
	m5b_q20_5	m5b_q22_5	Cad software (computer aided design)	1
	m5b_q20_6	m5b_q22_6	Statistical analysis or other analysis	1
	m5b_q20_7	m5b_q22_7	Software programming	1
	m5b_q20_8	m5b_q22_8	Managing computer networks	1
	m5b_q20_9	m5b_q22_9	Other (specify)	
	m5b_q20_9_other	m5b_q22_9_other		
			Minimum Score	0
			Maximum Score	19