Economic Watch

Employment vulnerability to the digital revolution: some stylized facts on Argentina, Colombia, Mexico, Peru and Turkey

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Abstract

We analyze different aspects of the likelihood of job automation in a selected sample of emerging economies: Argentina, Colombia, Mexico, Peru and Turkey. By means of national household surveys and the probability levels that Fred and Osborne (2013) estimated using a Gaussian process classifier, we find that the average probability of automation of the workforce ranges between 54% and 64%, where Argentina has the lowest level. In contrast, Peru and Mexico are the countries with the highest average risk of automation. In general, the countries show similar patterns in different aspects, such as distinctions by gender, age and education levels.

We found that the workforce with a high probability of automation varies between 61% in Peru and 30% in Turkey, which translates into 60.5 million people at high risk of being automated by adding the five countries analyzed. There are common characteristics for groups of countries. For example, Peru and Mexico share characteristics among the population with high probability of automation, which are: population at the end of the distribution, without education or with very low educational levels, informal, in small and micro enterprises, and in sectors such as agriculture or restaurants and hotels. In Argentina and Colombia the percentage of employment with a high probability of automation is around 40% (43% in Colombia, 40% in Argentina), and young people in sectors such as commerce, restaurants, and financial services have the highest probability of automation. In the case of Turkey, although employment with a high probability is lower in comparison, the characteristics are similar to those of Argentina and Colombia: workers under 33 years of age, with secondary education (similar to Colombia) and in sectors such as trade and financial services are the most vulnerable.

1. Introduction

Technological advances in recent years have shown that many of the functions that were previously developed exclusively by people can now be performed by a computer, and there are also products and services that not long ago looked like fiction that are now produced in the real world. These facts have brought new concerns about the labor market, since activities that were previously developed by a large mass of workers can now be easily accomplished, sometimes more efficiently, by a machine. This raises questions on the impact of the technology in the workforce, especially for occupations with manual or routine cognitive tasks. Some of the consequences that are outlined are the destruction of jobs, creation of new jobs, change in preferences on the qualification of workers, unemployment and income inequality.

Although the future of work is uncertain, a first step to mitigate the possible disruption of technological advances on labor is to know which occupations are the most affected (automatable) and what characterizes them, thus having a base on which to design policies specific to the reality of each country. The productive business structure, legal framework and level of education are key factors when analyzing the degree of automation for each country.

A pioneering research in the calculation of automation in the labor market is that of Frey and Osborne (2013), in which the authors calculate the percentage of occupations that are at high risk of automation. To do this, they use the 702 database of occupations in the United States and calculate the probability of automation based on the degree of substitutability of their functions with a machine in the near future. To this end, they take into consideration whether the tasks performed in each occupation are related to perception and manipulation and whether these have functions of creativity and social intelligence. In this way, it is obtained that 47% of the employment in the United States has a high probability of being automatable, affecting mainly low-skilled and low-wage jobs.

Frey and Osborne (2013) describe a route for the calculation of the level of automation, which have helped researchers to explore other countries under the same methodology. For example, Bowles (2014) finds that, on average, 54% of occupations in Europe have a high probability of automation, while Pajarinen and Rouvienen (2015) find that for Finland and Norway this figure is 35% and 33% of total employment, respectively; Bonin et al. (2015) estimate that the figure for Germany is 42% and Fuei (2016) calculates that in Singapore it reaches 25%.

These figures are expected not to imply a massive destruction of employment. The adoption of digitalization and the use of new technologies will not be abrupt. Instead, it is envisaged that it will be an adaptation process depending on the capacity of absorption and creation of new economic facilities. With this, current occupations can be maintained although with some changes in the functions and capabilities of the worker.

Thus, following the work done by Domenech, García, Montanez and Neut (2018), we investigate the characteristics of the vulnerability of occupations to automation in five emerging economies: Argentina, Colombia, Mexico, Peru and Turkey. First, we start with the latest available household survey for each country. As detailed in the annex of the paper, we make an aggregation and unification for each country's data to be compatible with the probabilities presented in Frey and Osborne (2013). Once we conduct the corresponding probabilities from the surveys, we make clearer comparisons among the countries under consideration in terms of the levels of automation. Additionally, we check the shares of employment for each country along different dimensions to identify relevant distinctions.

Our results show that the percentage of employment with a high probability of automation is higher in Peru and Mexico (61% and 52% of active population respectively), followed by Colombia and Argentina (44% and 40%) and finally Turkey where 30% of employment is in this situation of high vulnerability (Figure 1). Based on the characteristics of the active population most likely to be automated, Mexico and Peru share elements such as:

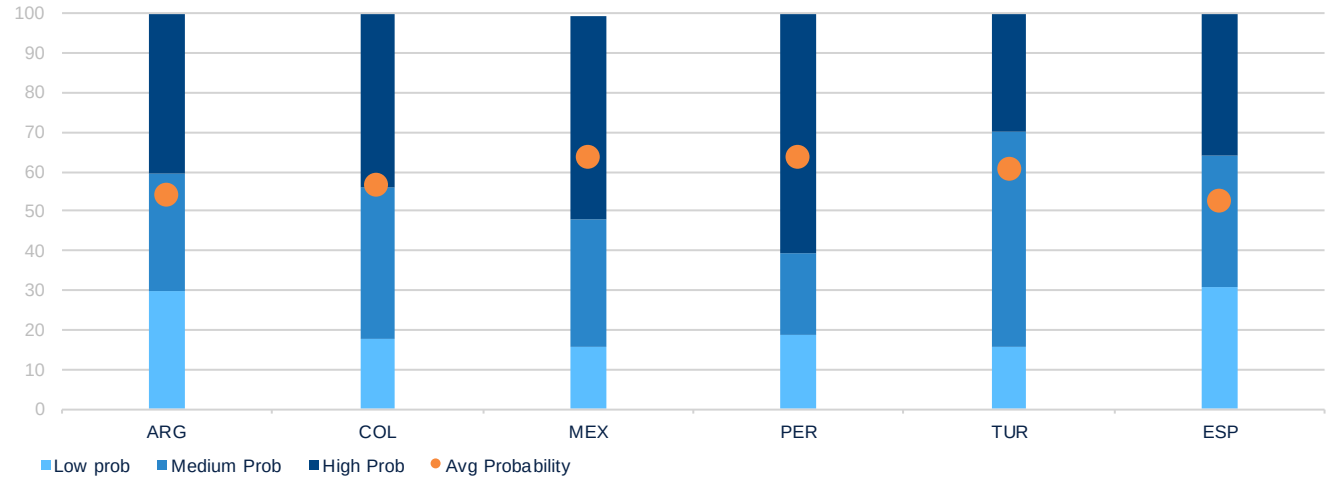
population under 33 and over 49, with no or low schooling, in the informal sector and in micro and small enterprises, particularly in sectors such as agriculture, or restaurants and hotels. In Argentina and Colombia, young people in particular, with low levels of education in sectors such as commerce and financial services (in Argentina) and construction and restaurants (in Colombia), have the highest probability of automation. Together, the population with a high probability of automation in these five countries sums 60.5 million people, compared to 23.3 million people with a low probability (less than 30% automation).

We show that the overall probability of automation ranges between 54% and 64% among the footprint countries, with the lowest probability in Argentina and the highest probability in Mexico and Peru. In order to understand the factors of this deviation in the level of automation between countries, we also analyze the different aspects in separate sections in the following order: Age, Gender, Education, Informality, Sector of Activity, Level of Income and Size of the Company. We also include an annex at the end of the paper to provide details in our calculations depending on the assumptions that we need to make due to the data constraints.

We work with unconditional probabilities to make simple comparisons. In the case of age, the youngest and the oldest have occupations with a higher likelihood of automation; this is consistent with the general observation that young people are employed at junior-routine positions while the olds lack the required knowledge to access newly formed occupations with a lower risk of automation (they would have received an education less consistent with the skills required in the age of digitalization). When gender is considered, no clear distinction occurs between the probabilities of automation among males and females, except in Argentina where females are at a significantly higher risk of having their current jobs automated. On the education side, it is clear across all the countries in the sample that a higher level of education is associated to a lower probability of automation. The level of informality is especially important in the analysis: informality ranges from 34% in Turkey to 73% in Peru, and it is linked with a higher likelihood of automation, partly because of the heavy concentration of occupations in the rural and commercial sector. On the other hand, public servants are exposed to lower probability of automation in all the countries since public administration and defense activities as well as education and health services all show lower probabilities of automation in all countries. In contrast, agricultural activities, manufacturing industry and certain services such as wholesale and retail sales, financial services, and restaurants and hotels all concentrate on occupations with higher probabilities of automation. The size of the firm is also crucial as we find that in all countries except for Argentina, larger companies provide jobs with a lower level of automation. And lastly, in all five countries, we find the well-known U-shape relationship between the probability of automation and income distribution.

In sections 2 to 8, we analysed all these aspects in further detail and also provide comparisons in terms of the shares of employment at high risk. In section 9, we draw conclusions and set next steps. We also include a methodological appendix in section 11 for the calculations for each country, detailing how we dealt with some difficulties when aggregating among the different classification codes used by each country in their national household surveys.

Figure 1. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

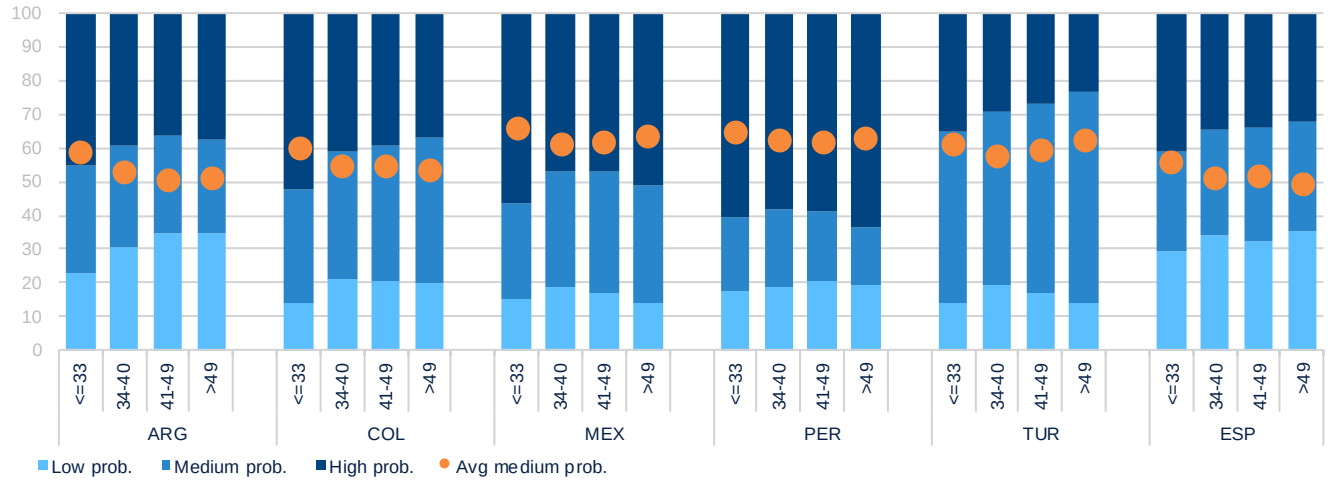
2. Age: younger and older people are more exposed to automation

In terms of age, the risk of automation is assumed to be higher for the young and old: older people would have received an education less consistent with the skills required in the age of digitalization while the young- even as they are educated to acquire the required cognitive skills-are generally employed at entry level positions that need less skills or less experience. Hence, the analysis on automation in terms of age is expected to reveal that younger and older people are more exposed to automation than the rest.

Except for Colombia, all analyzed countries exhibit the expected pattern in automation in terms of age. The probability of automation for younger people, lower than 33 years old, ranges from 59% to 66% while the range for older people, higher than 49 years old, is wider and extends from 51% to 64%. Moreover, the average probability of automation of jobs among young people is higher than the overall average for all countries whereas the probability of automation in jobs performed by the oldest people surpasses the overall average probability only in Turkey.

The proportion of employment with a high probability of automation stands out, especially in the case of Peru, but also in Mexico (Figure 2), which is especially striking in age queues: in Peru 64% of employees over 49 and 60% of employees under 33 have a high probability of automation, which compares with 56% in young people and 51% in older people in Mexico. In Colombia it is also slightly more than half (52%) of employees with less than 33 years in high probability of automation. In Turkey, in contrast, the bulk of workers are have average probability of automation (between 30 and 70).

Figure 2. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO AGE** (% OF ACTIVE POPULATION, PROBABILITY)



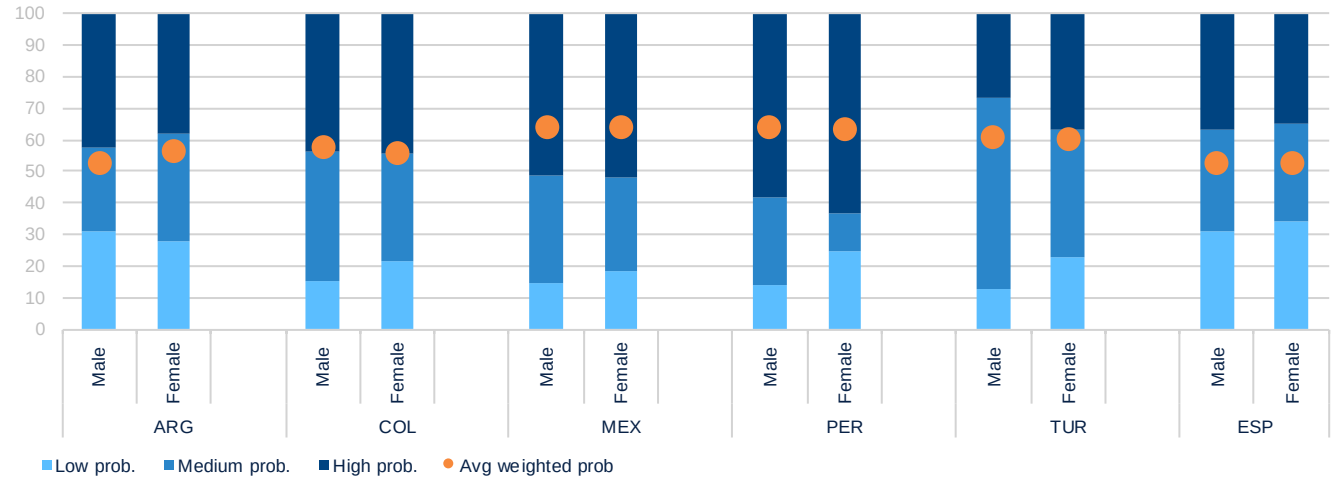
Source: BBVA Research

The young generation is an especially important concern for long-term development. This data confirms that governments should reassess educational programs especially in STEM disciplines (science, technology, engineering and mathematics) together with vocational training that provide the necessary skills in the age of digitalization. As seen in the “Human Capital Project” by the World Bank, to close human capital gaps and inequalities, members of society need to realize their potential from a very young age, investmenting in their knowledge, skills, and health.

3. Gender: similar average probabilities of automation between genders, yet shares at high risk are not the same

Females are less represented in the fields of science, engineering, information and communication technologies (UNESCO, 2018); additionally, according to the background report of OECD for the conference on "Improving women’s access to leadership: What Works? (2016), they are also employed at lower shares in the professional and managerial positions. The discussion on gender discrimination has been continuing for a long time. Hence, females are expected to be more exposed to automatization than males. However, according to our study in emerging countries, the probabilities of automation for male and female are very close to each other. Hence, the risk of automation does not exhibit any gender bias in these countries. Turkey, Mexico and Peru have probability of automation for both genders above 60% while Colombia and Argentina have a 52% and 58% probability, respectively. Furthermore, except Argentina and Mexico, females have slightly lower probability of automatization than males. The percentage of employment with a high probability of automation is more than half in Peru (63% and 58% in women and men respectively) and in Mexico (52%) (Figure 3). In Turkey, there is slightly more of a difference between men and women, with women employees being the most at risk of automation: 36% of employment, in contrast to 26% of employment in men.

Figure 3. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO GENDER** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

Employment for both genders is concentrated in occupations with high probability of automation in Peru (58% in males and 64% in females), while in Turkey employment for both genders concentrates in occupations with medium probability (63% in males and 43% in females). In the case of Argentina, the distribution of the employment is more balanced across occupations with differing risk profiles; though, the employment shares for both males and females are tilted towards low probability occupations, which accumulate 43% and 38% of the employment share, respectively. A balanced distribution is also observed in Colombia, where the employment shares for both males and females is tilted towards high risk occupations, with 44% each. In Mexico,employment is further concentrated in high-risk occupations(shares above 50% for both genders).

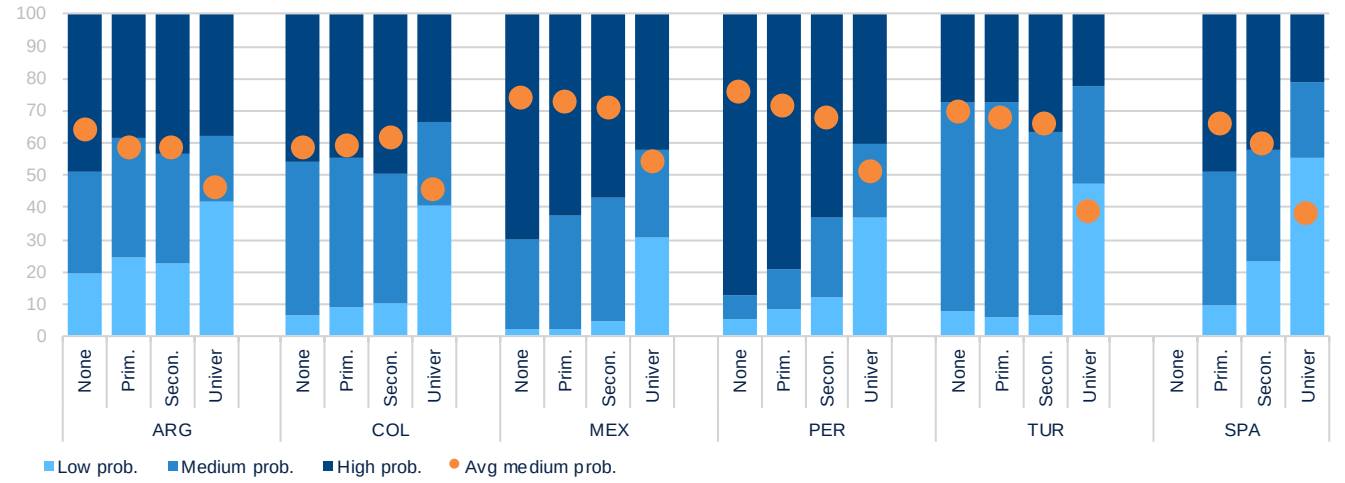
Human capital is a central driver of sustainable growth and poverty reduction. Investments in human capital have become more important as the nature of work has changed and it should not be considered without the participation of more women. Indeed, it is vital for governments to allocate more funds in education and training for both genders in order to decrease the probability of automatization. Secondly, some incentives to encourage more females to attain science and engineering degrees should be a top priority. Finally, businesses should also facilitate access to professional and managerial occupations via leadership training programmes for women.

4. Education: the higher the level of education, the lower the probability of automation of associated jobs

The level of education as a determinant of the probability of automation is significant in our sample. As expected, the higher is the level of education of a worker, the lower is the risk that his/her job will be replaced by a machine. This pattern is clearly seen for high education across the sample. Particularly in Colombia, reaching secondary education shows no risk reduction relative to achieving only primary education. This is aligned with the growing consensus on the importance of education and training, fostered in the firm or obtained independently by workers, in order to improve not only traditional knowledge but also different soft skills (teamwork, creativity, critical thinking, etc.). As can be seen in Figure 4, the proportion of employment in Peru with low levels of education (nil or primary) at risk of automation stands out. This percentage is as high as 87.1% of employment without education and 80%

with only primary education have more than a 70% probability of automation. In the case of Mexico, these proportions are also high, although somewhat less: 70 and 62% for no educational level and primary education respectively, and are somewhat lower than 50% in Argentina and Colombia.

Figure 4. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO EDUCATION** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

The empirical evidence puts alert on those occupations that require little qualification (associated with lower educational levels) or that are totally routine, while on the other hand, it is expected that the demand for highly qualified professions will increase, for which it is necessary to have a solid instruction, supported by university degrees and specialization, supplemented by "non-regulated" training actions that contribute to continuous training. Workers of the future would spend more time on activities that machines are less capable of, such as managing people, applying expertise, and communicating with others. On the other hand, they will spend less time on predictable physical activities, and on collecting and processing data, where machines already exceed human performance. The skills needed will also shift, requiring more social and emotional aspects, and more advanced cognitive capabilities, such as logical reasoning and creativity.

To this aim, the appropriate recommendation could be imminently invest in more and better human capital so that the population gains new knowledge and skills that accompany the technological progress (particularly in the so-called STEM disciplines: science, technology, engineering and mathematics). It is key to educate in communication skills and continuous learning. The increasing automation in routine cognitive processes involve changing the paradigm of "accumulating knowledge in order to work", and reveals the growing importance of continuing education as a key to professional development as it provides the flexibility to change and diversify competencies over the entire working career of workers. In this respect, there is a vital need for more qualified and flexible education to boost the human capital.

5. The role of informality: informal occupations are more likely to be automated

Informality is a salient feature in emerging economies. Hence, it is crucial to understand the dynamics of automation in terms of formality of jobs and according to whether they are in the public or in the private sector. Informality ranges from 48.5% of jobs in Argentina, to 72.8% in Perú. In Colombia and Mexico the rate is close to 60%. In the case of Turkey informality is much lower as it stands at a still significant 34%. The share of public employees is 3.7% and 7.2% of total workers in Colombia and Peru, respectively, and between 12% and 19% in Turkey, Argentina and Mexico.

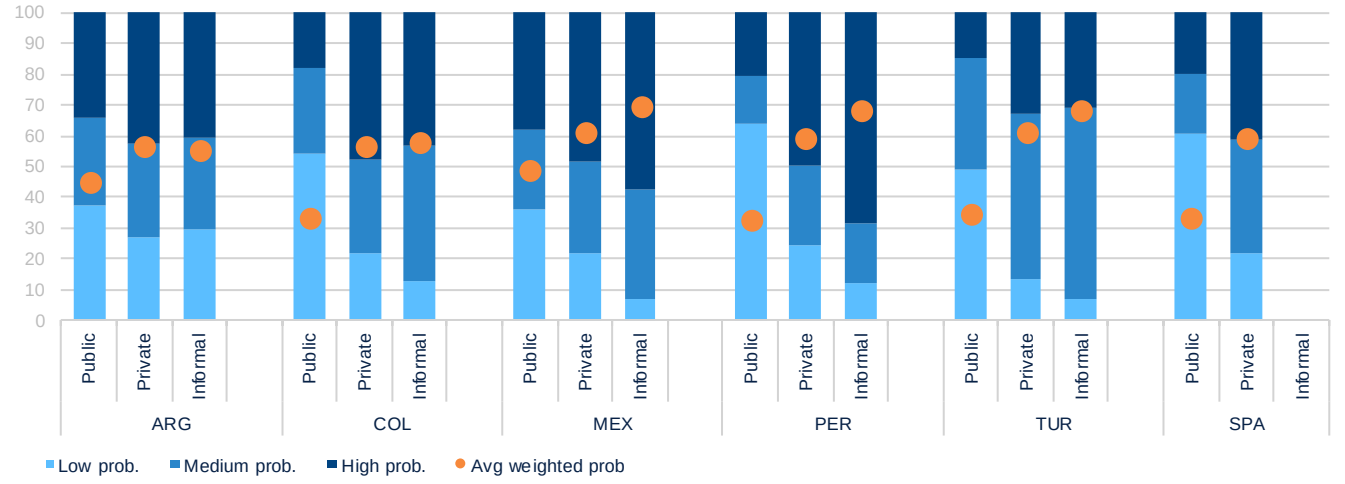
Jobs in the informal sector have the highest average probability of automation, reaching close to 70% in the case of Mexico, Turkey and Peru. In contrast, we observe that occupations of public employees have the lowest average probability of automation, ranging from 33% in Colombia and Perú to 49% in México.

Average probabilities of automation among informal jobs are 8pp, 6pp and 5pp higher than the corresponding general probabilities in Turkey, Mexico and Peru, respectively (see figure 5). The higher probability of automation in the informal sector seems due to the strong concentration of occupations in the rural sector and as traders, cooks and waitresses. Public jobs show automation probabilities on average 20pp below the country averages. The occupations in the public sector are significantly composed by teachers and, in the case of Colombia, by "firefighters, police officers, detectives, watchmen, prison guards" too.

Figure 5 shows the automation probabilities of the public, private and informal sector and the share of jobs in low, medium and high risk of automation on each sector's total job. It is worth noting a significant part of the employment in the public sector with low risk of automation, which represents on average 48% of total public jobs for the countries under study. On the other hand, in LATAM4, jobs with high risk of automation predominate among the informal sector (the share is on average 53% of total informal job). In the case of Turkey, it is the medium risk of automation the one that predominates among the informal sector.

Informal workers are characterized by low productivity, explained by low levels of social protection and low incomes, among other factors. Informality has consequences not only in the short term but also in the long term, as the states will have to eventually cover part of the costs of sustaining an older population that has never paid social security contributions. Reducing informality must be a priority. In terms of automation, going from informal private to formal private jobs would reduce countries average probability of automation by 5pp.

Figure 5. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO INFORMALITY** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

6. Sector of activity: high differentiation among the footprint countries

In general, and as has been found by various authors, Frey & Osborne, OECD, McKinsey, the probability of automation is greater in sectors or tasks where physical work is performed in predictable environments, such as fast food preparation or manufacturing industry. Conversely, the jobs where human interaction is important, such as education and health services have a lower probability of automation. It should be remembered that Frey and Osborne's paper estimates how existing activities may be affected, and it is not task-based. The probabilities of automation described in this section are based on occupations and not on tasks, whereas it is possible that within the same occupation, a worker may develop different tasks.

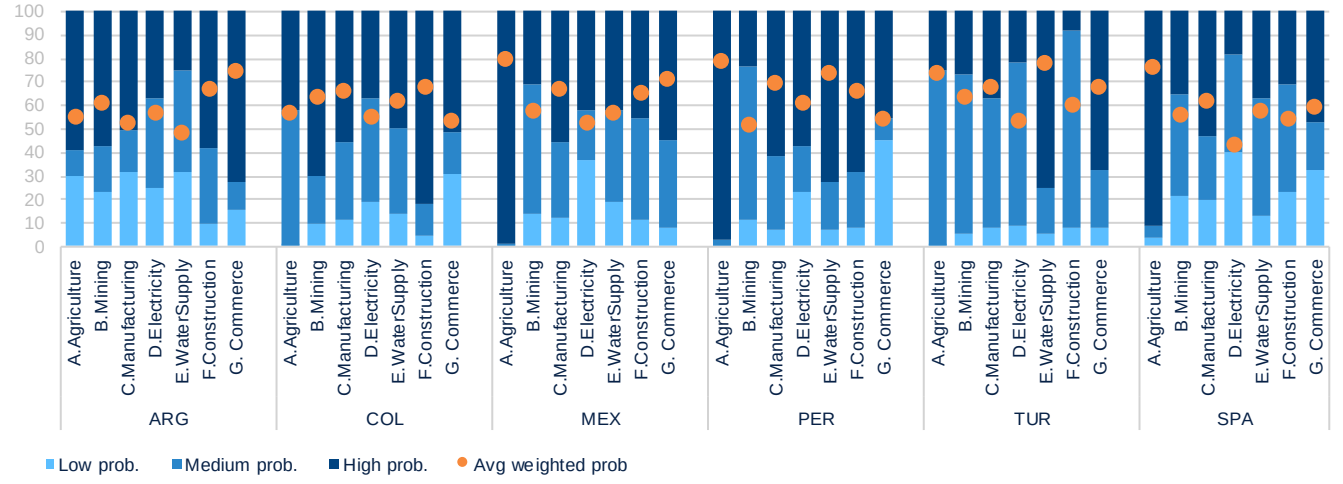
In the following graphs (6-8) we have divided the 21 sectors of activity into 3 groups of 7 sectors each. In the first group, primary and secondary activities, agricultural activities stand out, particularly in Mexico, Turkey and Peru, with an average probability of automation of 69%, 74% and 79%, respectively. In these three countries, the share of the active population employed in these sectors is 13%, 25% and 18%, respectively, being one of the activities that has a high level of employment share. In the case of Argentina and Colombia, the probability of automation in the agricultural sector is much lower at 55% and 57%, respectively. It is worth highlighting the high proportion of employment (basically all) with high risk of automation in Peru and Mexico. The other main subsector with a high probability of automation in a cross-sectional approach is the manufacturing industry, in which for all the countries, except for Argentina, the probability is above the national average. It is 68% in Turkey, 70% in Peru, 61% in Mexico and 67% in Colombia. Focusing on the sectors of this first group with a high probability (Graph 10), it highlights, in addition to the agricultural sector, the high probability of automation in occupations of the only activity of the tertiary sector included here, which is the retail and wholesale sector; this high probability is so for all countries except Colombia.

Among the second group the sector that tends to stand out for occupations with high probability of automation is "Accommodation and food services", particularly in Peru and Mexico, while the opposite case we observe in activities related to professional services. It should be noted that this sector (professional services) is among those that stand out in terms of occupations with low probabilities of automation. Among the sectors with the highest

probability of automation, the financial services sector stands out in practically all countries. It should be noted that both restaurants and hotels and in financial services, there are the highly repetitive-same environment activities, which is a characteristic present in occupations with high probability of automation.

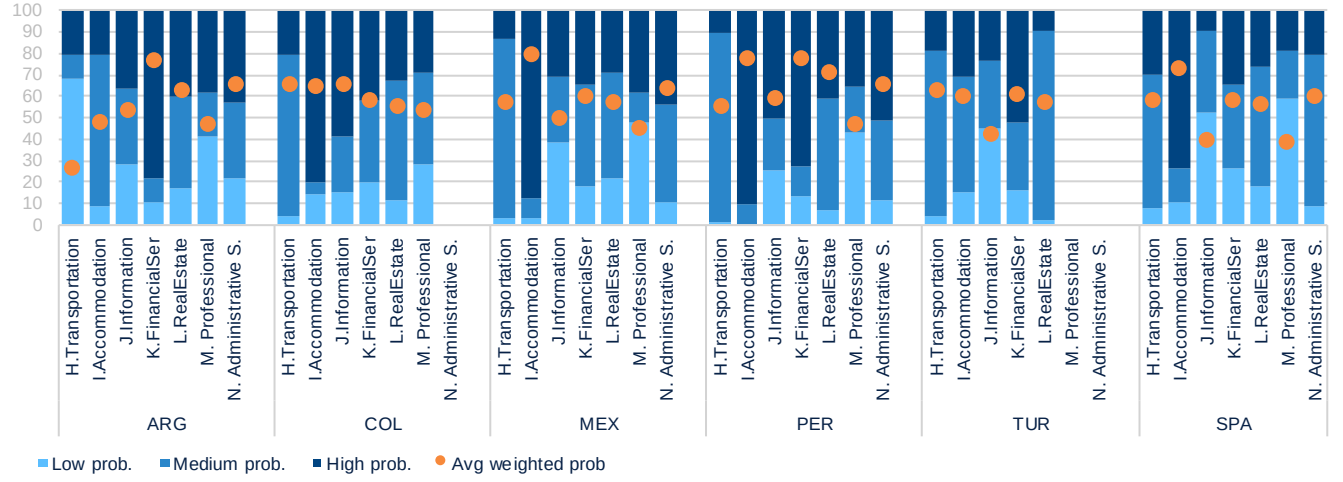
Finally, in group 3, Education and Health Care clearly stand out among the sectors demanding occupations with low probability of automation. This is true for all countries, as can also be seen in the extreme probability graphs. Education-related activities are found here at all levels: from primary school teachers (given the difficulty of a machine replicating the work of a human) to procurement managers who work in the same sector but facing a very high risk of automation. Health and social services also stand out for their low probability of automation in all countries except for Peru. In these two sectors, both education and health services, the common factor is the social interaction that is difficult to replace by a robot.

Figure 6. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO ACTIVITY SECTOR (GROUP 1)** (% OF ACTIVE POPULATION, PROBABILITY)



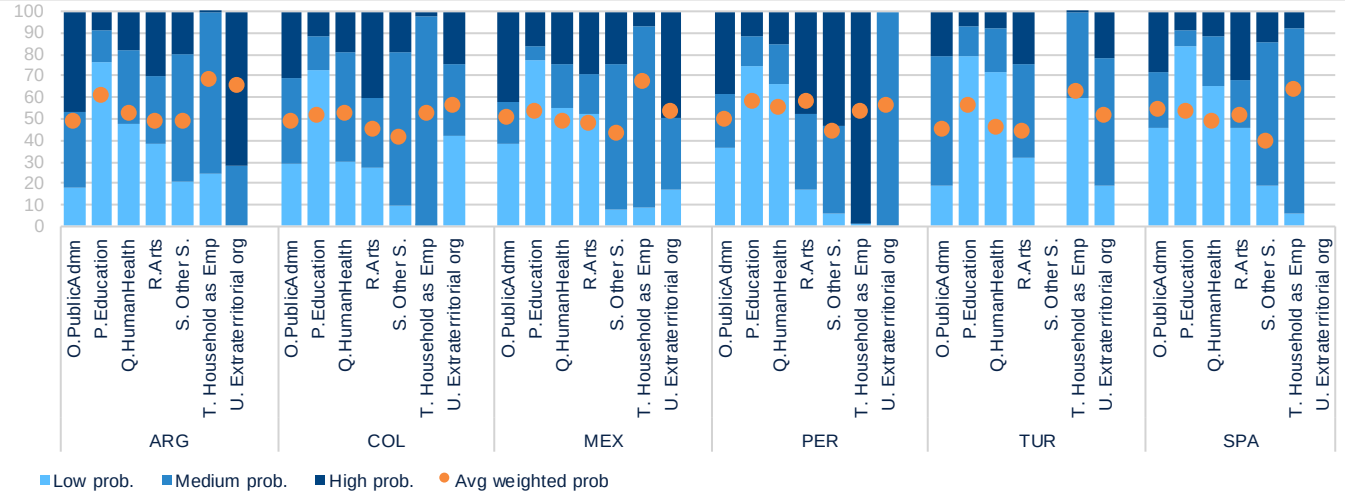
Source: BBVA Research

Figure 7. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO ACTIVITY SECTOR (GROUP 2)** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

Figure 8. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO ACTIVITY SECTOR (GROUP 2)** (% OF ACTIVE POPULATION, PROBABILITY)



Source: BBVA Research

7. The probability of automation tends to decrease with the size of the company

The analysis of the distribution of companies by size is essential because, in general, the size of the firm is positively associated with its productivity. It is an indicator of the efficiency of work and capital in the production of goods or services. On the one hand, it is expected that certain unobservable characteristics of the firm (e.g., the entrepreneurial capacity of its owners) associated with higher productivity facilitate the utilization of more work and capital, and therefore be large and productive. On the other hand, increases in the firm's scale of production may imply gains in productivity through lower unit costs and other benefits that are associated with scale.

In the countries under analysis,except Argentina, there is a pronounced concentration of workers in companies that employ between 1 and 10 workers (72% of total jobs in Peru, 68% in Colombia, 55% in Turkey and 33% in Mexico), suggesting the likely high degree of inefficiency that could be corrected with task automation. As a counterfactual, in the United States this figure barely reaches 5%[1]. According to the Corporación Andina de Fomento (CAF, 2013), it is a reality that in Latin America there are some sectors working in small informal businesses, basically self-employed, with very low levels of both productivity and income-generating capacity. This phenomenon explains why this high rate of entrepreneurship is not necessarily reflected in greater dynamism. Most of these firms have no prospect of expanding their activities, of generating employment or of steadily increasing production.

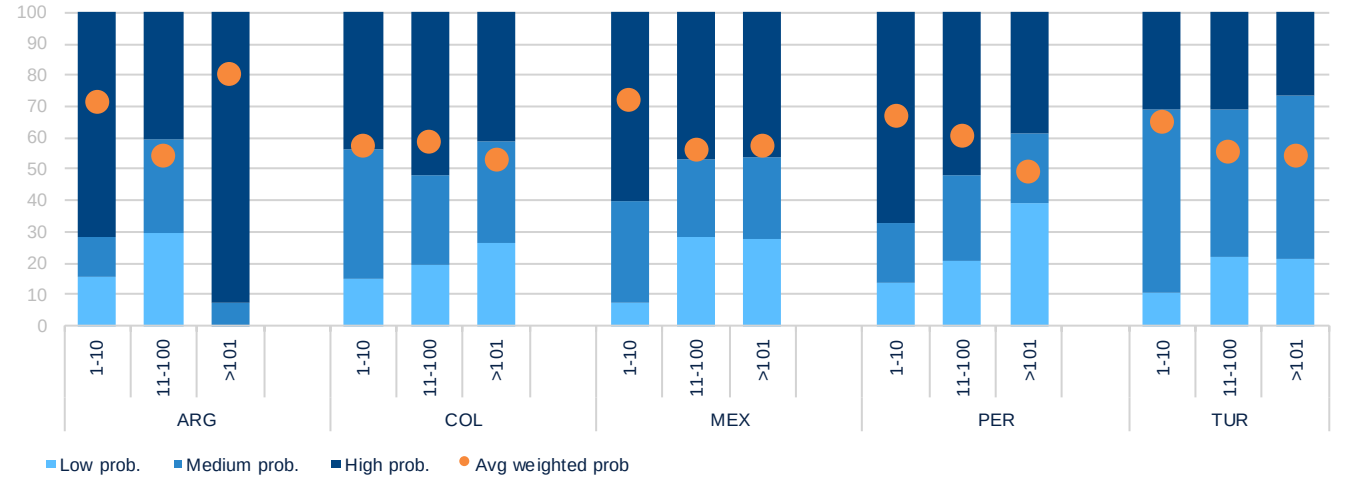
It is then not surprising that we find that the probability of automation is higher in smaller companies for most of the countries except for Argentina. Self-employed workers tend to be involved in businesses with low productivity or low qualifications which are easily automated, as well as many small family businesses. In the case of a non-paid worker, although it highlights its high probability of automation, it represents only a small portion of the population.

1 CAF (2013).

In Argentina, the probability of automation is strikingly high in large companies, not only because it is opposite to what occurs in other countries where automation is biased towards SME´s, but also because it is at a pronounced level of 80%. One reason is that in Argentina large firms in terms of the number of employees are retail companies and banks, which have processes and tasks with a high probability of being automated (cashiers, promoters, telemarketers, repositories, storage tasks, etc.). Although these large firms are also present in the other countries, unlike Argentina, these companies share the top positions in terms of staff rankings with energy companies, electronic technology companies, internet and telecommunications service providers or financial services firms, industries that are supposedly less likely to be automated because they require professions whose probability of automation is less than 50% (e.g.: Electronics engineers, 2.5%; Software developers, 4.2%; Financial and investment advisers, 23%; Research and development managers, 1.7%; Telecommunication engineers, 2.5%; Mechanical engineering technicians, 48%; Computer and information research scientists, 1.5%; Economists, 43%; Process control technicians, 36%; Legal and related associate professionals, 41%; Electrical mechanics, 38%, etc.).

Finally, to strengthen employment and improve efficiency under technological change, authorities need to eliminate barriers to start a company and follow up on the processes that guarantee efficiency. It is necessary to remove institutional obstacles to job creation, investment and enterprise growth in order to give rise to new occupations and new forms of facilities boosted by technological progress.

Figure 9. **EMPLOYMENT WITH HIGH / MEDIUM / LOW PROBABILITIES OF AUTOMATION AND AVERAGE PROBABILITIES, ACCORDING TO SIZE OF THE FIRM** (% OF ACTIVE POPULATION, PROBABILITY)



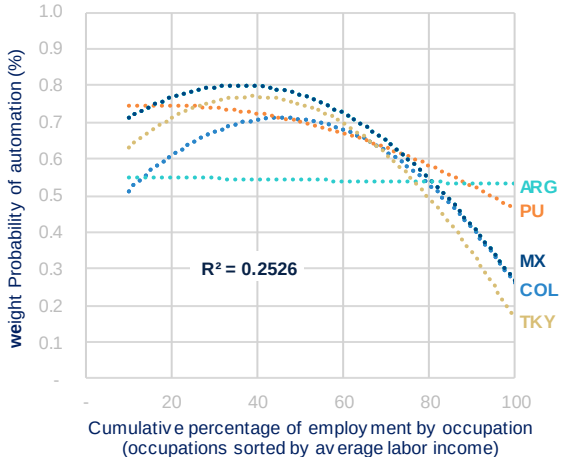
Source: BBVA Research

8. Probability of automation and income level

The literature refers to an inverted U-shape relationship between automation probability and income level. Autor, Katz and Kearney (2008) found, based on U.S. data, that, in the face of technological change, the share of employment in very low- and very high-skilled occupations has been increasing, while the share of employment in moderately skilled occupations has been contracting. This is because, according to them, "information technology complements highly educated workers engaged in abstract tasks, substitutes for moderately educated workers performing routine tasks, and has less impact on low-skilled workers performing manual tasks". In that sense, Frey & Osborne say, referring to Autor and Dorn (2013) that they “suggest that computerization may have contributed to a flattening at the center of the distribution of average wages. Furthermore, net changes in US employment were U-shaped in skill level, meaning that the lowest and highest job-skill quartile expanded sharply with relative employment declines in the middle of the distribution’. Among the occupations mentioned by Autor et al (2008) as manual non-routine and therefore qualified by them as "extraordinarily difficult to computerize" are service jobs such as health aides, security guards, orderlies, cleaners, and servers. In the same sense, Díez, Doménech and Neut (2018), find that in the case of Spain, as in the United States, "routinisation is more intense in occupations located at the centre of the distribution of average wages.”

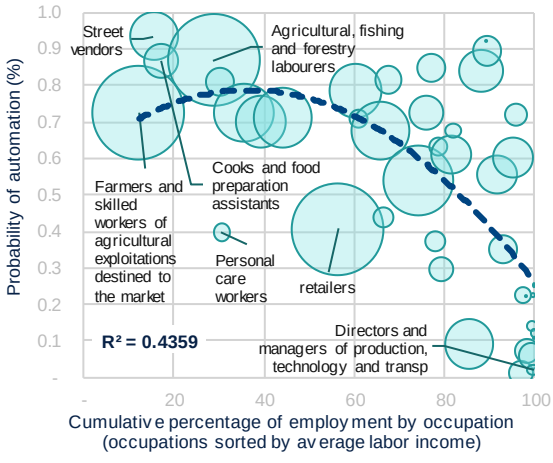
Graph 10 contains the probability of automation by deciles of mean income by occupation. A graphic illustration seems to show an inverse U-Shape for the cases of Colombia, México and Turkey (graph 9). In the case of Peru, the inverse U-shaped form is not obtained since relatively high probabilities of automation are observed in the lowest part of the income distribution. That is explained by the high participation of agricultural occupations in that range of the income distribution, occupations with high risk of automation. That is illustrated in Figure 11 to 13 which shows the probability of automation of each occupation (vertical axis) and the occupations are ordered by their mean labor income from lower to highest (on the horizontal axis). Bubble size in the graph is proportional to occupation size. In Peru, in the lower part of the distribution of income there are only occupations with probability of automation higher than 0.7, as workers in the agricultural sector, street vendors and cooks and food preparation assistants.

Figure 10. **PROBABILITY OF AUTOMATION BY DECILES OF MEAN INCOME BY OCCUPATION** (WEIGHTED PROBABILITY BY SIZE OF OCCUPATION, % OF TOTAL WORKERS)



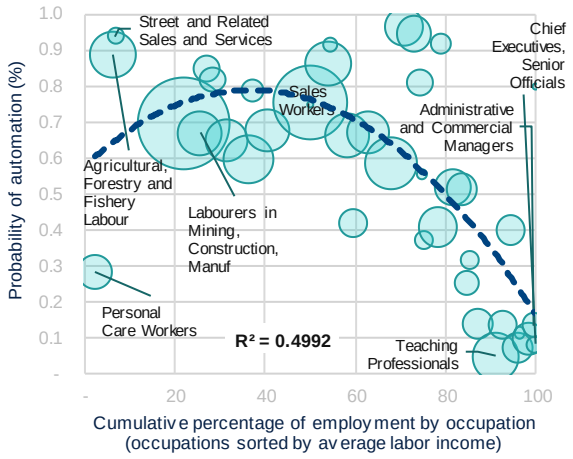
Source: BBVA Research

Figure 11. **PERU: PROBABILITY OF AUTOMATION BY OCCUPATION AND INCOME*** (%, % OF TOTAL WORKERS)



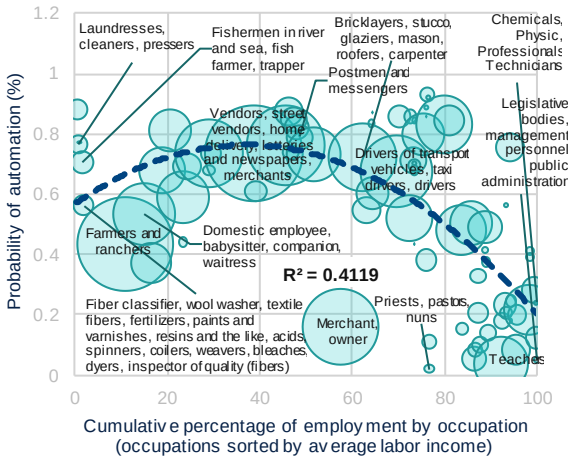
Source: BBVA Research. *For graphic ease this graph was done with the two digit occupation classification. The result using the 4 digit classification goes in the same sense.

Figure 12. **TURKEY: PROBABILITY OF AUTOMATION BY OCCUPATION AND INCOME**
(%, % OF TOTAL WORKERS)



Source: BBVA Research

Figure 13. **COLOMBIA: PROBABILITY OF AUTOMATION BY OCCUPATION AND INCOME**
(%, % OF TOTAL WORKERS)

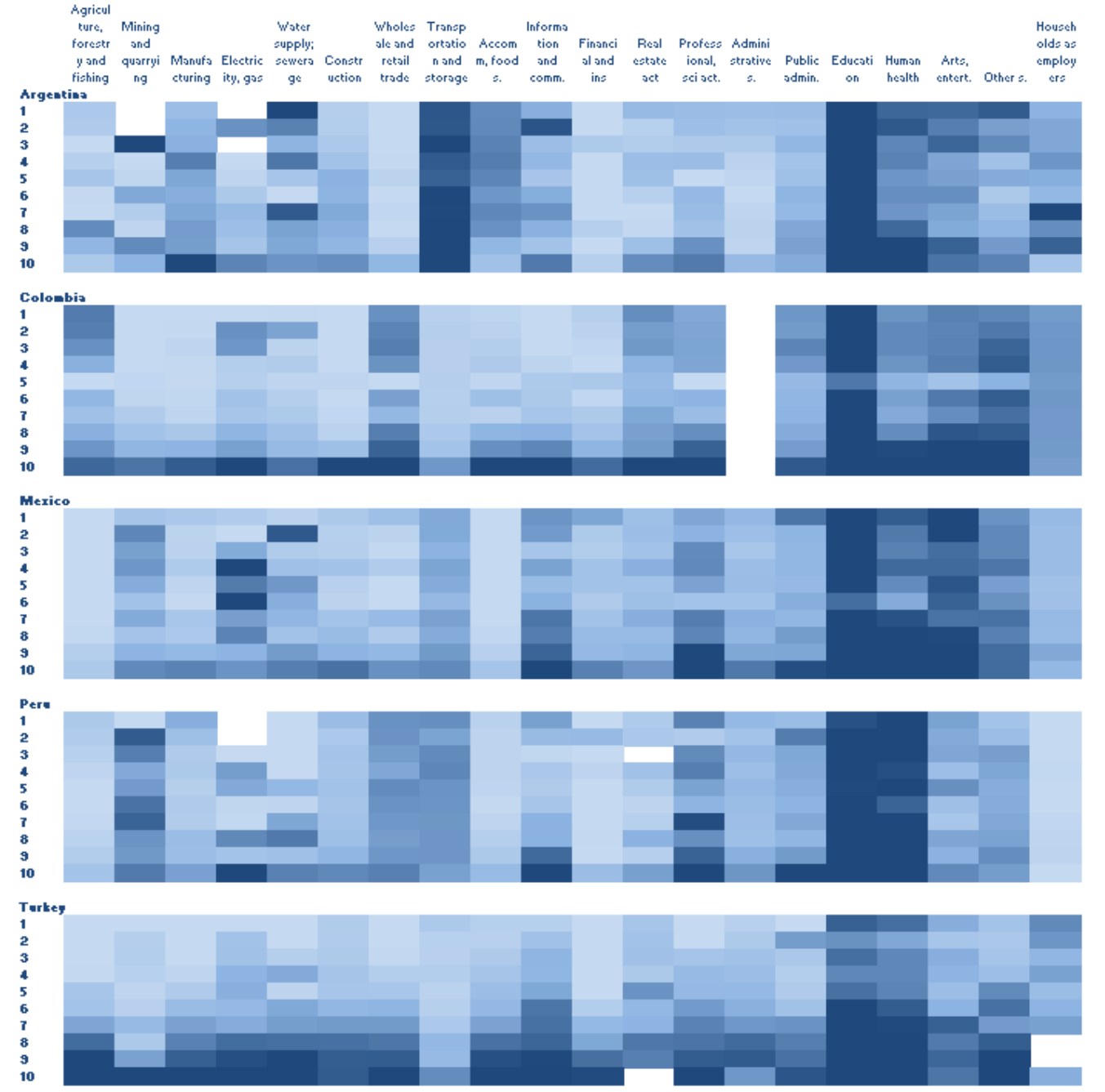


Source: BBVA Research

Figures 11 to 13, show the examples of Peru, Turkey and Colombia. It can be seen that at the bottom of the income distribution there are mostly jobs characterized by predictable, repetitive and physical tasks and therefore with high probability of automation. But, there are also in that range of the income distribution, occupations with lower probability of automation, those where human interaction is important - such as babysitter and companionship, for example. That is in line with the inverse U shape of the distribution. At the top of the income distribution there are occupations that presuppose high levels of education, such as legislators, managers, CEOs, physicists, surgeons and chemists, among others, which have low risk of automation. In that part of the income distribution are found the lowest probabilities (weighted and unweighted) of automation.

Looking by sectors, the occupations with the lowest probability of automation are in education, social services and arts and entertainment (see figure 14). The sectors more likely to be automated are mining, agriculture and water supply, as discussed in Section 6. However, the level of labour income plays an important role in the probability of automation: workers with incomes in high deciles have a lower probability of automation, especially in countries like Colombia and Turkey even if they work in sectors that concentrate occupations with a high probability of automation. In contrast, regardless of income level, the probability of automation tends to be low in some sectors such as education services, and in most countries health-related services, which may be related to the difficulty of automating these services.

Figure 14. **PROBABILITY OF AUTOMATION AND INCOME LEVEL (DECILES) BY SECTOR OF ACTIVITY**
(THE DARKER THE BLUE, THE LOWEST THE PROBABILITY OF AUTOMATION)



Source: BBVA Research

9. Conclusions

A series of studies have concluded that the recent digitalization era might lead to widespread technological unemployment. Frey and Osborne (2013) claimed that 47% of US jobs are at high risk of being automated. Our paper makes use of their estimated probabilities for occupations listed in SOC-10 codes. We estimate the automatibility for five emerging economies following the occupation-based approach proposed by Frey and Osborne's article. Our data suggest that 61%, 52%, 44%, 40% and 30% of jobs in Peru, Mexico, Colombia, Argentina and Turkey, respectively, have a high risk of automation.

Moreover, it is not surprising to find similarity in general trends those countries: the youngest and the oldest have occupations with a higher likelihood of automation; on the education side, it is clear that the higher the level of education is associated with a lower probability of automation; also, the informality is linked with a higher likelihood of automation; on the other hand, public servants are exposed to lower probability of automation in all the countries; the size of the firm is also crucial as we find that in all countries except for Argentina, larger companies provide jobs with a lower level of automation; and lastly, in all five countries, we find the well-known U-shape relationship between the probability of automation and income distribution.

We expect our work will foster a conversation and future research on the many dimensions of digital transformation in emerging economies.

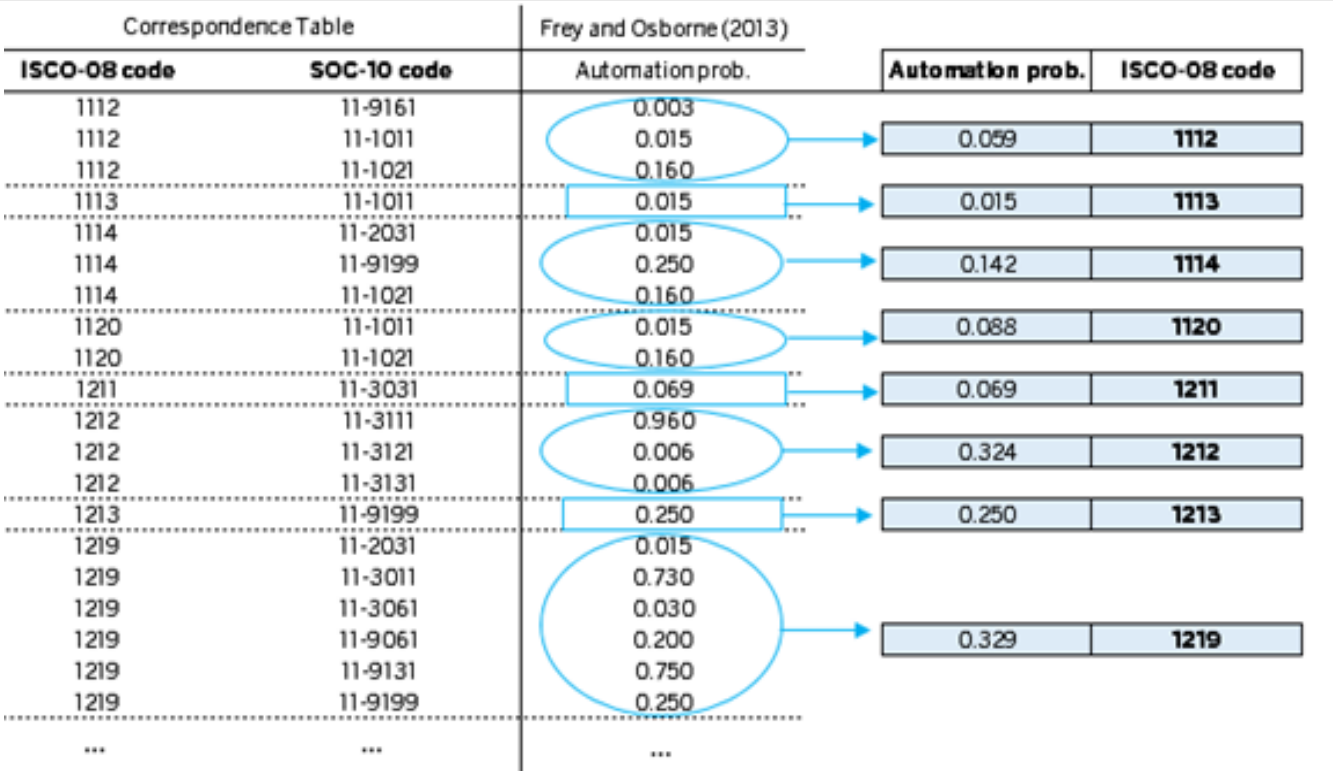
10. Methodology

The calculation of the probabilities of automation for Argentina, Colombia, Mexico, Peru and Turkey is based on those found in Frey and Osborne (2013). The authors estimate a probability of automation for each of the U.S. occupations found in the 2010 Standard Occupation Classification (SOC-10). To do so, they use the O*NET database that describes the functions and skills required for each occupation and approximate the possibility of automation according to the world advances in Machine Learning and Mobile Robotic in 70 of the activities listed. After that, they project the results to the rest of SOC-10 occupations.

Thus, because each of the countries studied has its own classification of occupations, the pairing with the SOC-10 codes has been achieved thanks to the International Standard Classification of Occupations 2008 (ISCO-08), created by the International Labour Organization (ILO) that serves as an intermediate step between different national codes and the SOC-10.

Thus, as a first unifying step for all countries, automation probabilities were calculated for each of the four-digit ISCO-08 codes (maximum disaggregation) with the help of an ISCO-08 versus SOC-10 correspondence table. The pairing logic is shown in Figure 15: the probability assigned to each ISCO-08 code is the same as the corresponding SOC-10 code and, if there are several associated SOC-10 codes, a simple average is taken from them.

Figure 15. **METHODOLOGY TO CALCULATE THE PROBABILITY OF AUTOMATION OF ISCO-08 CODES BASED ON FREY AND OSBORNE** (2013)



Source: BBVA Research

The following is a description of how the matching of the classifications of each of the countries was achieved with the ISCO-08, whose four-digit codes already have a probability of automation calculated in the previous step.

For Argentina, the Permanent Household Survey (EPH) is used to analyze the labor market for the country's urban areas, whose information corresponds to the first quarter of 2018. This survey uses the National Classification of Occupations 2001 (CON-01) where the maximum disaggregation gives each occupation 5-digit codes. Due to the fact that the CON-01 is constructed independently by the statistical institution of Argentina and does not have an official table of correspondence with the ISCO-08, a manual pairing was carried out. This crossing of information was done looking for similarities between the descriptions of codes CON-01 and ISCO-08, with which each code of CON-01 would have one or more associated ISCO-08 codes. After that, each CON-01 code is assigned to the average probability of automation of the associated ISCO-08 codes. This gives an automation probability for each of the occupations found in the Argentina survey.

The case of Colombia is totally different, where the National Household Survey classifies occupations with two-digit codes, so that in the survey there are only 82 different codes where each is described as a group of occupations. We work with information from the 2017 national survey and look for the probability of automation for each of the 82 codes. Colombia's National Classification of Occupations (CNO-70) is based on ISCO-68, but it has been possible to find the correspondence table of ISCO-08 versus CON-70 (a draft given by the Colombian National Department of Statistics .DANE-); however, this correspondence is with the maximum disaggregation of the CON-70 to five digits and not to two digits as shown in the survey. Therefore, the first step was to calculate the automation probability of each of the five-digit CON-70 codes with the ISCO-08 information calculated in the first

step. The five-digit codes were then grouped according to their first two digits and the average probabilities for each group were calculated. This resulted in an automation probability for each of the 82 codes and was incorporated into the national survey.

On the other hand, the cases of Mexico and Peru are similar, although for Mexico information from the National Household Survey was used for the third quarter of 2018 and for Peru information from the year 2017 was used. Both countries have their four-digit national occupations classifications and both are based on ISCO-08. That is why the official tables of correspondence between the national codes (SINCO-11 for Mexico and CNO-15 for Peru) versus ISCO-08 could be obtained, which facilitated the process. Because each national code is associated with one or more ISCO-08 codes, where each code already has a probability found in the first step, the automation probability for each national four-digit code is calculated as the average automation probability of the associated ISCO-08 codes. Finally, this is included in each country's national survey.

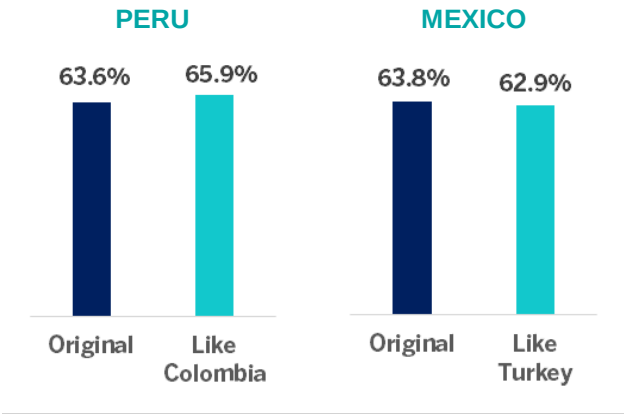
Finally, for Turkey, the probability calculation was slightly simpler because its national survey uses the ISCO-08 codes, albeit at two digits. For the calculation, the ISCO-08 codes were grouped from four digits into the first two digits by taking the average of the probabilities of automation calculated in the first step (to be more precise, the figures above or below two standard deviations are excluded from the average). Hence, automation probabilities are calculated for each of the 40 two-digit codes that ISCO-08 has and was included in the national survey.

This is how automation probabilities were obtained for each country's particular codes found in their national surveys. However, as in the case of Colombia and Turkey the surveys only show two-digit codes, 99 and 40 groups respectively, validity exercises were performed on the calculations to find out whether or not the probabilities found have a large margin of error. It was found that, although their occupation codes are aggregated, the probability is similar in comparison to if they had a disaggregated code.

For the validity of the results in Colombia, we worked with information from Peru. A variable was created that assigns to each four-digit code in Peru a two-digit code of Colombia- The imputation was based on descriptions of occupations. Thus, the classification of occupations in Peru ended with 82 categories, to answer the question what would have happened to Peru's probability of automation if it had had a classification similar to that used in the colombian survey. When calculating the probability of automation of Peru by applying the two-digit classification CON-70 of Colombia (the variable called “like Colombia” in graph 16) its similarity to the one found when calculating it with 4 digits is observed (the variable called “original” in graph 16). That similarity in the probabilities between "like Colombia" and "original" persists when greater levels of disaggregation are reached (by age and by educational level, for example), as shown in figure 17.

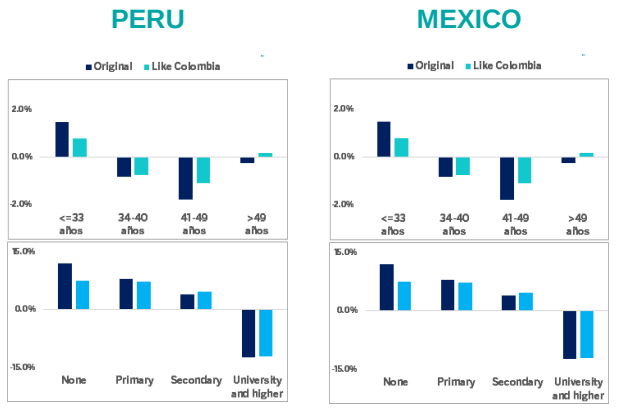
In the case of Turkey, it also appears that double-digit disaggregation does not alter the meaning of the results. The validity exercise was done with Mexico's national household survey to which a new variable was added associating national four-digit codes (SINCO-11) with ISCO-08 two-digit codes (used in Turkey's national survey). Because the relationship between the two codings is known, the imputation was based on the official correspondence table. With this, the question could be answered as to what would have happened to the probability of automation in Mexico if instead of having the classification SINCO-11 to four digits it would have had the ISCO-08 to two digits. When calculating the probability of automation of Mexico by applying the two-digit classification ISCO-08 of Turkey (the variable called “like Turkey” in graph 16) its similarity to the one found when calculating it with 4 digits is observed (the variable called “original” in graph 16). That similarity in the probabilities between "like Turkey" and "original" persists when greater levels of disaggregation are reached (by age and by educational level, for example), as shown in figure 17.

Figure 16. **COMPARISON BETWEEN ORIGINAL RESULTS AND VALIDATION EXERCISES**



Source: BBVA Research

Figure 17. **COMPARISON BETWEEN ORIGINAL RESULTS AND VALIDATION EXERCISES FOR AGE AND EDUCATION** (IN TERMS OF DEVIATIONS WITH RESPECT TO GENERAL PROBABILITY)



Source: BBVA Research

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