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SKILL-BIASED TECHNOLOGICAL CHANGE: THE CASE OF THE MENA REGION

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ABSTRACT: *Our work treats the relationship between inequality and technological change. Specifically, we focus on the transmission mechanisms by which technological innovation affects inequality in access to employment. The objective of this article is to determine the effect of the diffusion of innovation on the demand for skilled and non-skilled labour. It focuses on the concept of technological bias and the role of inequality between skilled and unskilled workers. The empirical validation of this work is based on the technique of*

the dynamic panel. An estimate using the method of Arellano and Bond seems more relevant. There is a positive relationship between innovation and the demand for skilled labour but a negative relationship with unskilled labour. This result is confirmed in our sample of countries.

KEY WORDS: *Technological change, inequality in access to employment, skill-biased technological change, complementarity between capital and skilled labour.*

JEL CLASSIFICATION: J21, J23, J24, O33, Q55.

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1. INTRODUCTION

The World Bank now considers reducing inequality as a priority, and in its 2005 Report it highlights the need to reduce “inequality traps”. However, this problem is more complex in Middle East and North African (MENA) countries where a paradox has been highlighted (Hassine 2015, Johannesen 2015): despite a substantial improvement in human development indicators, these countries have not experienced a significant reduction in inequality. The most recent data from the World Bank shows that the Gini index in the MENA region is relatively large, between 30 and 40. It therefore appears that the problem of equality goes beyond traditional education and health issues, underlining the importance of defining the main determinants of inequality in the region.

Inequality is a challenge not just for the poor but for the whole of society, as it undermines social cohesion and impedes social mobility, fuelling social tensions that can lead to civil unrest and political instability. Income inequality is a social phenomenon present in every country in the world, but to varying degrees. In some countries, such as in the MENA region, income inequality generates revolution and political instability. The waves of protest that have affected MENA countries since 2011 are partly the result of inequality and rising poverty in the region. Revolution in the MENA region is born of the refusal to tolerate the glaring socio-economic inequalities perpetuated by the elite, installed in power for too long. The issue of what causes inequality in many countries today and how to reduce it is at the forefront of national and international discourse.

Adding to an abundant literature on inequality and growth, we discuss the role of innovation as a source of inequality, following an analysis of biased technological progress (Aghion and Howitt 1998, Rubart 2007) and, more generally, the idea of “creative destruction” proposed by Schumpeter. So, innovation creates both inequality and profit opportunities. Therefore, what are the implications of technical change in the labour market? How do new technologies affect employment and wage distribution?

Technological change replaces the tasks previously performed by unskilled labour, favours more skilled workers, and increases inequality. This judge mentis based on decades of major change in technology, including the rapid spread of computers in the workplace and in our lives, which has resulted in wage inequality. In the United States, for example, the university premium - the salaries of university graduates compared to the wages of non-university graduates – rose by more than 25% between 1979 and 1995, and overall income inequality also

rose sharply. In 1971 a worker at the 90th percentile of the wage distribution earned 266% more than a worker at the 10th percentile. In 1995 this number reached 366% (Acemoglu 2002).

Several researchers have found a direct causal relationship between radical technological developments and changes in the distribution of wages in the US economy. This is summarized in the title of Krueger's 1993 article on computers and inequality, *How Computers Have Changed the Pay Structure*. The installation and operation of new technology often involves the acquisition and processing of information, and competence facilitates this adoption process. Therefore periods of rapid technological advance are associated with skill performance. Greenwood and Yorukoglu (1997) argue that we are now in the midst of a 'third industrial revolution', fuelled by advances from the information technology revolution that is responsible for the increase in inequality.

Various studies have reported an increase in the wage premium provided by university education compared to secondary education. For example, Bradbury (2002) assessed the link between schooling and wages in the 1980s and 1990s in the United States. The author observed an increase in the "wage premium of schooling", which he defines as the extent to which well-educated workers earn more than less-educated workers. The benefits of education have increased in recent decades, which is a significant cause of the growth in wage inequality.

Goldin and Katz (1998) argue that the spread batch and continuous process production methods increased the demand for skills. They add that: "...the change in electricity, after steam energy sources and water power, is enhanced because it reduces the demand for unskilled manual workers in many tasks like pulling, carrying and assembling". Capital-intensive industries greatly increase the demand for skills (Goldin and Katz 1998).

Griliches (1969) suggested that capital and skills are complementary. Nelson and Phelps (1966), Welch (1970), Schultz (1975), and Tinbergen (1975) showed that technological developments increase the demand for qualifications. Personal computers, computer-assisted production techniques, and robotics complement skilled workers by replacing many highly labour-intensive tasks. The increase in inequality over the past decades can be seen as a direct consequence of technical change. The thesis of Skills-Biased Technological Change (SBTC) explains the inequality of wages and of job access. Indeed, this thesis shows that technological change is biased towards skills. Technological change is always accompanied by

unequal pay and unequal access to employment between skilled and unskilled workers.

For this purpose, we present a review of the theoretical and empirical literature on this issue. Next, we outline our specified model and the data we have used for empirical validation. Finally, we compare some of the theoretical hypotheses, using econometric tests on panel data to verify the impact of technological change on employment demand for our sample of countries.

2. LITERATURE REVIEW

The adoption of new technologies requires a high level of human capital, which is frequently scarce at the beginning of the technology diffusion process. Given this scarcity, we are witnessing an increase in skilled workers' wages while other workers' wages are maintained at their original level, resulting in wage inequality. If new technologies are more complex than the old ones, there is a positive correlation between wages and the use of the new technologies.

The SBTC hypothesis is confirmed by estimating the equations that link non-manual workers' employment share on the one hand, and R&D expenditure and computer use on the other hand. Berman, Bound, and Griliches (1994) showed that computers and R&D spending have a positive and significant impact on increasing non-production workers' share of the payroll. Focusing on the period 1979-1989, Allen (2001) showed that, in most industries, the wage gap increased when the level of R&D rose.

Autor, Katz, and Krueger (1998) got similar results for sectors other than production in the United States, which formed an increasing demand for skilled labour after 1970. They argued that the diffusion of computers and technology significantly contributed to this phenomenon, and showed that the evolution of skills occurred more quickly in computer-intensive industries. As a whole, the empirical evidence of Autor, Katz, and Krueger (1998) shows that more technologically advanced industries are more likely to show an increased demand for skilled workers.

By matching data from the industrial establishment and from employees, Doms, Dunne, and Troske (1997) showed that there is a positive correlation between new technologies and qualifications: institutions that use advanced production technologies are characterized by a higher share of skilled workforce. Goldin and

Katz (1998) studied the impact of new technologies and new production processes during the first half of the 20th century, the period following the introduction of electricity. They found that there is a complementarity between new technologies and skilled workers. In particular, the dissemination of production techniques related to the use of electric motors in the first decade of the century fostered an increase in the demand for skilled workers in the United States manufacturing sector.

For France, using a sample of 4,954 companies for the period 1991-1996, Duguet and Gennan (1997) showed the existence of a technological bias in the labour design of companies that favoured the most skilled workforce. In Canada, in an analysis of the industrial service sector, Gera, Gu, and Lin (2001) found the technological level indicators (stock of patents, age of the capital stock) to be positively correlated with use of skills, which aligns well with the SBTC hypothesis. This study confirms the results of Betts (1997), which showed that, over the period 1962-1986, technical progress was unfavorable to unskilled labour in most sectors of Canadian industry.

The work of Betts (1997) concerns 18 industrial sectors in Canada. He considers two categories of employment by occupation: production labour or blue-collar workers and indirect labour or white-collar workers. In 10 out of 18 sectors, tests reject the hypothesis that technological changes were neutral. Card, Kramarz, and Lemieux (1996) defended the idea that the same forces that lowered the real wages of unskilled labour in the United States also affected labour markets in Canada and France.

In a cross-sectional study, Bartel and Lichtenberg (1987) showed that the older the capital, the lower the share in labour costs of those with more than 13 years of education, indicating that the latest technologies are associated with a more skilled workforce. In an international comparison, Machin and Van Reenen (1998) found that industry in the United States is similar to that in other countries. They identified correlations between skilled labour and both capital and new technologies. These correlations were strongest in the United States and Great Britain.

Draper and Manders (1996) examined the example of the Netherlands. They considered two groups of sectors, protected areas and exposed areas, and two categories of employment by level of education: qualified (secondary and above), and unqualified (primary and extended primary). They found that technological changes are important. Indeed, most of the reduction in unskilled labour demand

can be attributed to efficient asymmetric technological changes in labour. They also confirmed the complementarity between capital and skilled labour.

Casavola, Gagosto, and Sestito (1996) used two job categories, blue-collar and white-collar, to show that the use of new technologies led to a shift in the relative demand for labour in favour of indirect employees during the second half of the 1980s. However, it was not obvious that an increase in the wage premium occurred simultaneously. Entorf and Kramarz (1997), in estimation with individual effects, found that all effects, excepting the experience of new technologies, disappeared. Companies selected their best employees when seeking people to work with new technologies containing data processing. These new technologies were used by employees who were already better paid than their colleagues before working on this equipment.

More recently, on a sample of 32 countries over the period 1980-1991, Conte and Vivarelli (2007) studied the consequences for the structure of the workforce in developing and least-developed countries of imported technology made in developed countries. They noted that there is a complementarity between capital and labour inputs (skilled labour and unskilled labour). However, imported technology helps to increase the skilled workforce and reduce the number of unqualified employees.

In developing countries, estimates of the effects of technological change on employment and wages remain rudimentary. To fill this gap in the literature we focus on such countries. Based on a sample from the MENA region, we will try to answer the following questions: What are the effects of technological changes on the demand for skilled and unskilled workers? What is the nature of the relationship between capital and skills and between technological changes and educational level?

3. EMPIRICAL ANALYSIS

3.1. Model and data

Our work is limited by a lack of data on wages by level of qualification. However, we rely on the specific effects of individuals represented by the term α_i to capture the changes in relative wages. We will focus on the impact of technological changes on inequality of employment access rather than inequality of wages or

income. According to panel data, our estimated employment equations have the following structure:

$$L_{it}^s = (1 - \alpha_1) L_{it-1}^s + \alpha_2 Y_{it} + \alpha_3 K_{it} + \alpha_4 TC_{it} + \alpha_5 PPP_{it} + \alpha_{it} + \xi_{it} \quad (1)$$

$$L_{it}^{us} = (1 - \alpha_1) L_{it-1}^{us} + \alpha_2 Y_{it} + \alpha_3 K_{it} + \alpha_4 TC_{it} + \alpha_5 PPP_{it} + \alpha_{it} + \xi_{it} \quad (2)$$

Our work estimates skilled and unskilled labour (explanatory variables) in terms of these two delayed variables, production, capital, technological changes and the purchasing power parity (explanatory variables). These models are inspired by the work of Sboui and Saafi (2012).

We will study these two equations in time and space where i represents each country and t represents each time period ($t = 1, 2, \dots, T$). L^s represent skilled labour measured by the number of workers with a university education. L^{us} is unskilled labour measured by the remaining workers (no education, primary level reached, complete primary level, secondary level reached, complete secondary level). Y represents production, K is the stock of capital, TC is technological changes, and PPP is purchasing power parity.

Our contribution is based on statistical data from several databases. The stock of capital is represented by share of investment in real GDP per capita. The data on the stock of capital are from Penn World Tables (Heston, Summers, and Aten 2012) version 7.1. Production is represented by real GDP per capita and drawn from the World Bank (WDI, 2014). PPP is from Penn World Tables (Heston, Summers, and Aten 2012). Skilled and unskilled labour are taken from the database of Barro and Lee (2010).

We choose to measure the technological changes first by the number of patents filed by residents and non-residents, then by spending on R&D as a percentage of GDP, and, finally, by the value of imported technologies as a percentage of the import of goods. The number of patents is taken from the World Intellectual Property Organization (WIPO 2010). Expenditure on R&D and the value of imported technologies are taken from the World Bank (WDI 2014).

In summary, we will test the SBTC hypothesis. By using two specifications, we will test the impact of technological change on the demand for skilled and unskilled workers and the inequality of access to employment for skilled and unskilled workers.

3.2. Research Methodology

The estimated employment demand function shows the presence of a delayed dependent variable. The presence of this variable represents a major difficulty. This complication originates from the correlation between the dependent variable delay and disruption, although ξ_{it} is supposed uncorrelated. The solution to this problem is based on the instrumental variables estimators, and consequently on an estimator by the Generalized Method of Moments (GMM) developed by Arellano and Bond (1991). This method solves the problems of simultaneity bias, reverse causality, and omitted variables that weaken results. The method of Arellano and Bond (1991) acts as a dynamic panel estimated in two stages, so we first rewrite the model in first differences to eliminate the individual and time-specific effects. The in-level lagged values of two or more periods are employed as a result of the instruments of the explanatory variables in first difference, assuming that the errors of the in-level equation are not serially correlated.

However, this instrumentation technique is somewhat inefficient, given that the delayed in-level variables are weak instruments for first differences. Blundell and Bond (1998) proposed a GMM model system, which consists of a model equation in first difference and a level in the initial equation model. Concerning the in-level equation, the predetermined and endogenous variables are instrumented in-level by their own first differences on the one hand, and the strictly exogenous variables are instrumented in-level on the other.

However, Blundell and Bond (1998) showed that if the instruments are weak, the estimator in two stages is biased in the case of small-sized samples. Our sample is composed of six countries in the MENA region: Algeria, Egypt, Iran, Malta, Morocco, and Tunisia. For the period 1965-2010, technological changes are measured by the number of patents, and for the period 1996-2010, technological changes are measured by spending on R&D and the value of the imported technologies. The results of our estimates are shown in Tables 1, 2, and 3.

Table 1: Estimation Results (technological change: number of filed patents)

| Equation (1) | Sys-GMM | Equation (2) | Sys-GMM |
|-----------------------------|----------------------|-----------------------------|-----------------------|
| Skilled Labour_1 | 0,0478** (0,000) | Unskilled Labour_1 | 0,0059** (0,000) |
| Production | 0,2478* (0,000) | Production | -0,0478* (0,003) |
| Capital | 0,7589*** (0,000) | Capital | -0,9783*** (0,003) |
| Technological Change | 0,9874*** (0,000) | Technological Change | -0,4587*** (0,000) |
| PPP | 0,4796** (0,000) | PPP | -0,6547** (0,000) |

Note: *, **, *** denotes significance at 10%, 5%, 1%; the values in parentheses represent probabilities.

Table 2: Estimation Results (technological change: spending on R&D)

| Equation (1) | Sys-GMM | Equation (2) | Sys-GMM |
|-----------------------------|----------------------|-----------------------------|----------------------|
| Skilled Labour_1 | 0,1598* (0,000) | Unskilled Labour_1 | 0.1256** (0,000) |
| Production | 0,4587** (0,000) | Production | -0.8974* (0,000) |
| Capital | 0.4785*** (0,000) | Capital | -0.5896** (0,000) |
| Technological Change | 0.3654*** (0,001) | Technological Change | -0.9874** (0,001) |
| PPP | 0.9852** (0,000) | PPP | -0.8947* (0,000) |

Note: *, **, *** denotes significance at 10%, 5%, 1%; the values in parentheses represent probabilities.

Table 3: Estimation Results (technological change: value of imported technology)

| Equation (1) | Sys-GMM | Equation (2) | Sys-GMM |
|-----------------------------|---------------------|-----------------------------|----------------------|
| Skilled Labour_1 | 0,9356* (0,000) | Unskilled Labour_1 | 0,5689* (0,000) |
| Production | 0,9854* (0,000) | Production | -0,1234* (0,000) |
| Capital | 0.6521** (0,000) | Capital | -0,6852** (0,001) |
| Technological Change | 0.7436** (0,000) | Technological Change | -0.9874* (0,000) |
| PPP | 0.2589* (0,000) | PPP | -0,3029** (0,000) |

Note: *, **, *** denotes significance at 10%, 5%, 1%; the values in parentheses represent probabilities.

The validity of all the instruments can be checked using Sargan’s over-identification test, which is based on the GMM estimator. From the results shown in Tables 1, 2, and 3, we can say that, whatever the chosen specification, Sargan’s over-identification tests do not indicate a problem in the validity of the instrumental variables. Since the statistics of these tests are below the thresholds, the null hypothesis is accepted: the instrumental variables are asymptotically uncorrelated with the disturbances of the estimated model and hence the selected instruments are valid.

When technological change is represented by the number of patents (Table 1), we found a positive and significant sign of production relative to skilled labour and a negative and significant sign of production relative to unskilled labour. Moreover, purchasing power parity has a positive and highly significant effect on skilled labour and a negative and significant effect on unskilled labour.

The signs of the coefficients of technological change and capital are in line with our expectations. We got a very positive and significant effect of technological change on the demand for skilled labour. A1-point increase in technological change or the number of patents is accompanied by an increase in the demand for skilled labour of 0.9874. This confirms the SBTC thesis. Similarly, a 1-point increase in capital is accompanied by an increase in the demand for skilled labour of 0.7589. In addition, we got a negative and very significant effect of technological change on the demand for unskilled labour: a1-point increase in technological change or in the number of filed patents leads to a decrease in demand for unskilled labour

of 0.4587. Similarly, a 1-percentage-point increase in capital goes hand in hand with a decline in demand for unskilled labour of 0.9783. This confirms the thesis of Griliches (1969) concerning the complementarity between skilled labour and capital.

The same result is found in cases where technological change is represented by R&D expenditure (Table 2). We reached a positive and significant sign of production relative to skilled labour and a negative and significant sign of production relative to unskilled labour. Purchasing power parity also has a positive and significant effect on skilled labour and a negative and significant effect on unskilled labour.

The signs of the coefficients of technological change and capital are again consistent with our expectations. We got a very positive and significant effect of technological change on the demand for skilled labour. Increased technological change and R&D expenditure are accompanied by an increase in the demand for skilled labour. Similarly, a capital increase is accompanied by an increase in the demand for skilled labour. We got a negative and significant effect of technological change on the demand for unskilled labour: increased technological change and R&D expenditure are accompanied by a drop in demand for unskilled labour. Similarly, an increase in capital is accompanied by a decline in the demand for unskilled labour. This confirms the thesis of Griliches (1969) concerning the complementarity between skilled labour and capital.

In cases where technological change is represented by the value of imported technologies (Table 3), we arrived at a positive and significant sign of production relative to skilled labour and a negative and significant sign of production relative to unskilled labour. An increase in production is correlated with an increase in the demand for skilled labour and a decrease in the demand of unskilled labour. On the other hand, purchasing power parity has a positive and significant effect on skilled labour and a negative and significant effect on unskilled labour.

Again, the signs of the coefficients of technological change and capital are in line with the theory. We got a positive and significant effect of technological change on the demand for skilled labour: an increase in technological change or the value of imported technology is linked to an increased demand for skilled labour. Similarly, an increase in capital is accompanied by an increase in the demand for skilled labour. We also got a negative and significant effect of technological change on the demand for unskilled labour: an increase in technological change or the value of imported technology is accompanied by a drop in the demand for unskilled labour. Similarly, an increase in capital is accompanied by a drop

in the demand for unskilled labour. This confirms the thesis of Griliches (1969) concerning the complementarity between skilled labour and capital.

We note that all the measures of technological change positively and significantly influence skilled labour and significantly and negatively influence unskilled labour. This work is intended to test the thesis of the technologies bias for a set of the MENA region through the use of dynamic panel models. Our econometric study proves the existence of a technological bias in favour of the most skilled workforce. Skilled labour is much more complementary to capital than unskilled labour. Moreover, the inclusion of different measures of technological change shows that this result is general: all types of technological change promote skilled labour. All the results of our estimates support the thesis of technological bias. The dissemination of technological innovation led to a permanent change in the structure of employment in favour of skilled workers.

Berman and Machin (2000), Conte and Vivarelli (2007), Sboui and Saafi (2012), and Ben slama and Plassard (2011) have all confirmed the SBTC hypothesis using panel data. Conte and Vivarelli (2007) used imported technology to represent technological change by . For Berman and Machin (2000), technology indicators are the use of computers and R&D. These two studies treated a sample of developing countries. Saafi and Sboui (2012) were interested in 9 industrial sectors in Tunisia. These authors found that technological diffusion leads to a change in the structure of employment in favour of skilled workers. They also found that increasing technological value raises the demand for skilled labour and reduces the demand for unskilled labour and that capital increase is correlated with an increase in the demand for skilled labour. In another study on Tunisia within the framework of the Alliance for Research on North Africa (ARENA), Iwasaki and Kashiwagi (2011) clarify the relationship between human capital and employment in Tunisia, estimating the effect of education performance on employment and salary. Taking into account the differences between the surveyed regions (Kebili, Monastir, Beja, and Tataouine), the results of their analysis confirm the positive impact of investment in education on productivity and labour income. Based on French data, Ben slama and Plassard (2011) contributed to the literature on the impact of new technology on the wages of employees who use a computer at work. Both authors confirmed the existence of a wage premium associated with the use of computers. All these results confirm the thesis of Griliches (1969) concerning the complementarity between capital and skills.

4. CONCLUSION

Many authors have posited that the issue of poverty and income inequality is one of the most urgent problems of our modern world, and that income inequality dramatically impacts people's daily lives. They have demonstrated that in a fair and equal society, homicide rates are lower, children experience less violence, and people are more confident. Inequality is still one of the dominant social facts in the MENA region and identifying the sources of inequality remains a crucial issue.

Quite often these are basic economic issues, which are the most difficult to deal with and respond to. The many scientific and sociological papers that deal with the problem of inequality are witness to its importance. The latest analyses of the origin and evolution of inequality can be broken down into two groups, depending on the direction of the relationship between inequality and technological change. The first trend is interested in the influence of technological change and growth on the evolution of inequality. The second trend deals, conversely, with the impact of inequality on technological change and growth. This study seeks to enrich the first debate by analyzing the relationship between inequality and technological change as a determinant of inequality.

We began by presenting a review of the literature SBTC. We empirically tested if technological change is a determinant of unequal access to employment in the countries of MENA region, where inequality is causing revolution, and confirmed the presence of SBTC. Thus increased technological change correlates with increased in equality in access to employment. We also found a complementarity between an increase in capital and skilled labour.

It is important to have redistributive taxation to avoid exclusion at the top and bottom of the income scale. To further promote social mobility, we must also have a tax system that distinguishes between innovation and other sources of inequality at the top of the income scale. In other words, we must not treat innovators in the same way as annuitants or pure speculators. A tax system that discourages innovation would not only hurt growth but also reduce social mobility.

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