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Digital transformation, development and productivity in developing countries: is artificial intelligence a curse or a blessing?

Heidi Aly
Department of Economics, Cairo University, Giza, Egypt

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Abstract

Purpose – The entire world is now witnessing the Fourth Industrial Revolution and Artificial Intelligence (AI) is indeed altering the lives of the many in both developing and developed countries. Massive digital transformations are affecting the economies of those countries and are bringing with them many promised merits, as well as many challenges to face. This paper aims to examine the relationship between digital transformation (as a one facet of the fourth revolution and AI trends) on one side, and economic development, labor productivity and employment on the other side.

Design/methodology/approach – The paper analyzes different indices of digital transformation, and then uses the Digital Evolution Index (DEI) to study those relationships in a group of developing countries using feasible generalized least squares method (FGLS).

Findings – The results show a positive relationship between the digital transformation index and economic development, labor productivity and job employment. Females seem to gain more from digital transformation compared to males, as suggested by the positive relation with the first and the insignificant relation with the latter. The relationship with vulnerable employment is not significant; more evidence is still needed to judge whether digital transformation will have an impact upon the vulnerable employees in the economy.

Research limitations/implications – The paper focused on the impact of digital transformation upon total aggregate employment. Future research is still needed to examine the impact upon the structure of the labor market and the shift of occupations.

Originality/value – The paper aims to add to in the literature regarding the relationship between digital transformation, economic development, employment and productivity in the developing world. The implications of those relationships are of significant importance to policymakers regarding how much support should be given to encourage the digital transformation. At the same time, it shall also indicate how much social support policies are required – if any – to lessen the negative impact of digital transformation on the vulnerable groups inside the country. Another contribution is using a single composite index for digital transformation that is comparable across the chosen set of developing countries, instead of using single indices each capturing a different dimension of digital transformation.

Keywords Developing countries, Labor productivity, Artificial intelligence, Economic development, Digital transformation, FGLS

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JEL classification – O1, O2, O3, O4

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1. Introduction

In the era of the Fourth Industrial Revolution, Artificial Intelligence and Digital Transformation, a major concern for both economists and policy makers has been the impact of those major changes on the way the economy functions. Particularly those changes are expected to affect, among others, the rate of development of the economy, employment rate and labor productivity. Digital transformation can ease matters for some, while making life harder for others. It could be an engine for speeding up the growth of the economy, and at the same time it could be a function in hindering this growth if the appropriate framework for its incorporation does not exist. The impacts are still uncertain and shall depend on a number of different factors including the level of development, the persistent level of unemployment, the size of population and the quality of human and physical capital.

This paper seeks to study the relationship between digital transformation, economic development, productivity and employment for a set of developing countries. The countries have been selected following the international classifications of developing and developed countries of UN (2019), UNDP (2019) and UNCTAD (2019) [1] using feasible generalized least squares method. The paper is interested in examining the impacts of digital transformation upon the sample of developing countries and accordingly come up with relevant and interesting implication for those countries. Another contribution is using a single composite index for digital transformation that is comparable across the chosen set of developing countries, instead of using single indices each capturing a different dimension of digital transformation. The used index is the digital evolution index (DEI) which reflects the overall stance of digital transformation inside the country and takes into consideration both the supply and demand sides of digital transformation.

Hence, the paper aims to add to the existing literature regarding the relationship between digital transformation, development, employment and productivity in the developing world. The implications of those relationships are of significant importance to policy makers regarding how much support should be given to encourage the digital transformation and the promotion of artificial intelligence. At the same time, it shall also indicate how much social support policies are required – if any – to lessen the negative impact of digital transformation on the vulnerable groups inside the country.

The results showed a positive relationship between the used digital transformation index and each of GNI per capita, labor productivity and employment. The increase in employment comes from the positive relation between digital transformation and female employment; women are expected to gain more from the digital transformation witnessed by the developing countries. The relationship with vulnerable employment was not significant (total, male and female). However, for the developing countries to reap those promised benefits of digital transformation, a number of elements should be taken into consideration. The paper is divided into three sections besides the introduction and the conclusion. Section 2 introduces the existing literature review regarding the impact of digital transformation including Artificial Intelligence on different macroeconomic variables. Section 3 provides a summary of recent measures of digital transformation in the literature. Section 4 presents the data, estimated model, results and implications.

2. Literature review

Digital transformation, as a new and modern term in business and technological literature, is usually defined as: "integration of digital technology into business that results in, changes in business operation and delivery of value to customers" (Mićić, 2017). It also refers to the transformations prompted by the massive adoption of digital technology that generate, process, share and transfer information. It builds on the evolution of multiple technologies: telecommunications networks, computer technologies, software engineering and the spillovers resulting from their use. In this regard, Artificial Intelligence is considered a very critical tool to accelerate digital transformation. According to Accenture Research (Accenture, 2018), "AI is the collection of multiple technologies that allow machines to detect, understand, act and learn either on their own or to augment human activities". Therefore, AI is considered as an important component and at the same time accelerator of the rapid digital transformation. Over the past few years, the popularity of those terms increased rapidly, and many people started to feel their impacts in different fields of the economy including business, medicine, finance and daily life. The examples are many including breakthroughs in disease detection, self-driving cars, virtual banking and auto pilots to name just a few.

Given this growing era of digital transformation including artificial intelligence, and its mounting popularity, an increasing number of studies have shown interest in examining the relationship between different forms of digital transformation and several macroeconomic variables. Variables of interest included, among others, output growth, labor productivity, employment, real wages, delivery of services and innovation. The majority of those empirical studies have been implemented on developed and emerging countries, while few studies have been directed to developing and lower income countries. The studies showed mixed results; the majority of it supports the positive impact of digital transformation. In this study, the interest is particularly upon the impacts related to growth, development and labor market.

The relationship between automation or digital transformation and economic growth is of substantial importance; digital convergence positively affects growth and development. Greater access to information and opportunities for technological cooperation can create job opportunities, transfer of skills, and greater efficiency and transparency in politics and business (Finger, 2007). World Economic Forum has identified ICT sector as one of the major sectors contributing to output growth. Additionally, it expects it to have influence on GDP growth from 1.4% in emerging markets up to 2.5 in China (Kvochko, 2013). Moreover, at the total economy level, Katz and Callorda (2017) estimated that a 1% increase in a digital ecosystem development index has the potential of 0.13% increase in per capita GDP. The coefficient is greater for OECD countries than emerging economies. Those positive consequences on growth do not necessarily take place immediately, indeed, Park and Choi (2019) showed that technological innovation advances take time to show impact upon the growth of the different economies, and for its effects to spread all over the economy.

Sabbagh *et al.* (2013) concluded that an increase of ten percent in a country's digitization score promotes a 0.75% growth in its GDP per capita. However, the implications of digital transformation are not the same across different countries. Across developed economies, digitization improves productivity and has a measurable effect on growth. However, the result can affect the availability of occupations because lower-skill, lower-value-added work is usually sent abroad to emerging markets, where human manpower is cheaper. By contrast, emerging markets are more oriented towards exports and are driven by tradable sectors. They tend to gain more from digitization's effect on employment than from its influence on growth. Jimenez *et al.* (2018) expects that by 2021, around 60% of the emerging markets' GDP will be derived from digital products or services created through digital transformation.

Jain (2018) further showed that AI could add up to US$320bn to the Middle East in 2030. The region is expected to gain 2% of the total global benefits of AI in 2030. This is equivalent to US$320bn. Additionally, the contribution of AI to growth would grow annually by a range of 20-34% per year across the region. Again, the gains are not the same for all countries; with the fastest growth in the Emirates followed by Saudi Arabia. This analysis is based on the current situation of the region. The potential benefits could be even larger if governments invest more on expanding innovative technical advances and implementation of AI across businesses and sectors. Those promising effects of AI on the economies of the Middle East can be explained through viewing AI as a new factor of productivity added to the existing factors of labor, land, capital and entrepreneurship. This consideration of AI as a factor of production is based on its self-learning capabilities that develop itself noticeably through time, and not just technology-based machines with higher levels of productivity and output creation.

By considering AI as the new factor of production, it has the potential to drive growth in at least three significant means: creating new workforce – virtual not real with higher productivity and efficiency and with also reduced cost of business process; a complementary and a facilitator tool to the current existing human and physical capital; and enhancing innovative advances and technological breakthroughs (Accenture, 2018). Those elements, together with the expected higher growth of revenues, the promotion of specific industrial sectors and the development of industrial value chains, all have the potential of positively affecting economic growth (OECD, 2019).

Furthermore, the impact of digital transformation does not only take place at the macro level. In this regard, Mackenzie (2018) estimated the economic potentials of *disruptive technologies*- defined as the advances that can transform life, business and the global economy – to be as wide as encompassing several individual effects and not just nation-wide aggregate ones; this include among others (a) reduction in the cost of computers and super machines; (b) 2-3bn more people with access to the internet in 2025; (c) tremendous increase in knowledge workers; and (d) substantial increase in usage of smart products (example autonomous cars) with much less errors.

Regarding the relationship between digital transformation and employment, the concerns that digital transformation could affect employment is not new; it could be traced as back as Aristotle's time when the issue was the implications of machines displacing human labor. The phrase "technological unemployment" was popularized by John Maynard Keynes in the 1930s, who viewed it as an "only a temporary phase of maladjustment". Later on, Schumpeter considered technological progress to be the center of the economic dynamics. He explained that innovation is the major source of disequilibrium in the economic system and a most likely weapon leading to its destruction. Schumpeter justified this with two elements:

(1) Technical advances that take place are not similar or the same across the whole economy; rather they tend to concentrate in specific sectors, leading to structural adjustments between them.
(2) Innovations lead to economic cycles with uneven growth periods (Freddi, 2018).

The destructive effect of artificial intelligence on employment tend to take many forms that could be viewed as different phases of evolution:

- changes in the way of work, i.e. changes in the tools used during the work process;
- negative impact on labor demand due to AI replace of human decisions;
- changes in management staffing and decision-making process to improve management efficiency;
- new technology creating new jobs since old sectors and industries will gradually be replaced by the new industries and departments; and

- increasing income of residents and raised standards of living as a result of reduced production cost, improved labor productivity and promoted economic development and social progress (Ping and Ying, 2018).

In a similar context, Dirican (2015) concluded that a number of consequences are to take place in response to the massive trends of artificial intelligence witnessed by many countries across the globe. Those consequences include structural changes in production, communication, marketing and staff costs, unemployment of low skilled human work forces, alteration of traditional economic concepts and their calculations like unemployment rate, the Philips Curve, Purchasing Power Parity, GDP and inflation. Eventually, Space Economy will be the new age with tremendous impacts on economies, business and daily life.

Regarding the empirical estimates of digital transformation including AI advances, the effects in most cases were huge and positive despite the existing negative theoretical underpinnings. For example, according to the World Economic Forum, ICT sector, in the USA alone, is expected to expand growth of number of jobs by 22% up to 2020. This goes almost up to 760,000 new jobs. In Australia, the expectation is quite similar and is estimated by almost 25,000 of new jobs annually created (Kvochko, 2013). Digital transformation including AI indeed creates jobs; with a 10-point increase in the digitization score leading to a 1.02% drop in the unemployment rate. Emerging markets have significant opportunities waiting for them to reduce poverty effectively and to raise standards of living substantially; by doubling the Digitalization Index score for the poorest population over the coming ten years, they have the potential of tremendous gains in their nominal GDP (estimated by roughly four and half trillion US$), in addition to over 60 million new occupations for the socially and economically most marginal groups. The ultimate effect is 580 million people to rise above the poverty line (Sabbagh *et al.*, 2013).

At the aggregate world level, Katz and Callorda (2016) also showed that between 2004 and 2015, an increase of 1% in the digitization of consumption index resulted in a 0.07% fall in unemployment rate. Furthermore, Goos *et al.* (2015) estimated the local high-tech job multiplier across European locations to be around five. However, it is worth noting that besides those positive impacts of digital transformation upon employment and job creation, some negative consequences did occur. Certain industries undergoing digital transformation of their production, contrary to creating jobs, were prone to reducing their workforce as a result of substituting their humans with AI machines (Katz, 2017). Empirical evidence showed that product innovation had positive impact on employment. However, and at the same time, the reduced demand due to the slowing down economic growth since the 1990s together with the increase in global competition among international corporations, both led companies to apply labor-costs-saving strategies and reduce available job opportunities.

In 2019, Earnest and Young (EY) announced its plans to hire 14,000 people for its Global Delivery Services (GDS) centers in India with the objective of strengthening its technical and consultancy services delivery network. EY is aiming to increase its workforce with emerging skills, in response to the sharp demand for digital transformation and innovation-led services from clients globally and in India. Respectively, according to (Kunming, 2019) each additional score gained in the Digital China Index has led to an addition of 660,000 to 2.39 million newly employed. In certain regions, the proportion of newly hired people in the digital economy reached 40% or more.

Not only does digital evolution affect the total number of job creation or losses, it also greatly affects the composition of the available jobs. Based on large representative panel data, Fossen and Sorgner (2018) provided evidence that significant effects of AI are observable at the individual level. In particular, there is a high risk that digital transformation would lead workers to either switch occupations or even to lose employment entirely. They found that the results differ between incorporated and unincorporated entrepreneurship, with the transformation risk higher in the second. In a similar context, using a survey among German firms, Arntz *et al.* (2019) found that cutting-edge digital technologies have little effect on total employment rate, but lead to large movements of workers between occupations and industries. Therefore, the main challenge of digital evolution will not be just the rate or number of occupations, but the structure of jobs and the equivalent need for supply side adjustments to meet the shift in demand both within and between occupations and sectors.

The coming section seeks to briefly summarize the different indices common in the literature that measure digital transformation and accordingly choose among them a relevant indicator(s) to the objective of the study.

3. Digital transformation indices and macroeconomic variables

Several institutions, studies and projects have shown wide interest in calculating indices that measure the stance of digital transformation across the different countries. In the following sections, the objective is to analyze the common indices in the literature and examine their relationships to GNI per capita, labor productivity and employment. Therefore, after exploring the different indices, the paper shall proceed in the analysis by choosing a particular index of digital transformation and study its relationship to the selected macroeconomic variables using econometric models.

One of the common measures of digital transformation is the *Digital Adoption Index* (DAI); it is a worldwide index that measures countries' digital adoption across three dimensions of the economy: people, government and business, and it stress more the "supply-side" of digital adoption. The overall DAI is calculated as a simple average of the three sub-indexes. Each sub-index includes the technological requirements necessary for promoting digital development, enhancing productivity and facilitating business broad-based growth (World Bank Group, 2016).

In 2018, Euler Hermes published the new edition of the *Enabling Digitalization Index* (EDI) with implementation on 115 countries with the objective of measuring their capabilities in guiding digital companies and in supporting traditional businesses. The index evaluates countries in terms of their support to digitalization, and hence ranks them according to digital-friendly regulation with its different institutional, logistic and technical aspects (Hermes, 2018). It therefore focuses on the organizational and enabling environment of digital transformation inside the country and on the support that government directs towards encouraging technical innovation.

Similarly, *The Digital Economy and Society Index* (DESI), is a composite index developed by Cámara and is being published every year by the European Commission since 2014. It focuses on EU countries in particular to measure the steps and procedures undertaken by those countries towards promoting the digital economy and society. It is constructed of relevant indicators on Europe's current digital policies. The DESI comprises five principal policies: connectivity, human capital, use of internet service, integration of digital technology and digital public services (European Commission, 2018).

Another index is *DiGiX* which is a composite index of 18 sub indicators calculated for 99 countries around the world. It aims to measure the degree of digitalization in those countries through gathering and classifying information related to three sides: supply conditions (infrastructure and costs), demand conditions (technical societal and governmental adoption) and institutional environment (regulations and logistics) (Cámara, 2018).

In a similar context, the DEI is a data-driven general evaluation of the progress of the digital economy across 60 countries, aggregating more than 100 different indicators across four key drivers: supply conditions, demand conditions, institutional environment and innovation and change. The index therefore reflects both the current situation of digital transformation inside the country, and equivalently the progress rate at which the country is improving. This has the potential of identifying and providing relevant implications for investment and innovation. This is achieved as a result of the interaction among four drivers:

(1) the country's digital infrastructure;
(2) the demand for technology;
(3) the institutional environment; and
(4) innovation and development.

It additionally provides highlights on the growing risks and challenges associated with the continuous dependence on digital technology (Chakravorti and Chaturvedi, 2017).

Due to data availability and relevance to the objective of the study, it was chosen to analyze three digital transformation indices that capture different dimensions of digital transformation and are at the same time available for the developing countries. Those indices are the DEI, the EDI and the DAI. It is believed that using a single composite index that covers those different dimensions of digital transformation and is at the same time standardized across the different countries has the potential of showing relevant and sound results. The relationship to the different macroeconomic variables is analyzed in the coming section.

4. Data and econometric model – analysis and results

This section seeks to examine the relationship between digital transformation and a set of macroeconomic variables. Specifically, the paper uses cross-section data for a group of 25 developing countries for the year 2017 to study the relationship between digital transformation on one side and economic development, labor productivity, employment and vulnerable employment on the other side. The section starts first by graphical analysis of digital transformation indices and their relationship to the selected macroeconomic variables. Second, it introduces the model specification and the data used in the model. It then continues by explaining the steps of the econometric methodology, and finally presenting the main findings of the model and the implications of the results.

4.1 Digital transformation indices and macroeconomic variables

Figure 1 shows the relationship between the selected digital transformation indices and economic development, measured by GNI per capita. It is very interesting to observe how the three indices show consistent results. The relationship is positive indicating that countries with higher digital transformation enjoy higher levels of GNI per capita. The position of the countries is even similar across the three indices, with Malaysia, Chile and Saudi Arabia at the upper-right of the figure enjoying high levels of both indicators, namely, digital transformation and economic development; while Algeria, Bangladesh, Bolivia and Cameron at the lower-left of the figure, experiencing low levels of both.

Figure 2 shows the relationship with labor productivity – measured as the ratio between real GDP and number of employees inside the country. Again, the relationship is positive and strong (as suggested by the slope of the fitted line), and again the consistency across the three

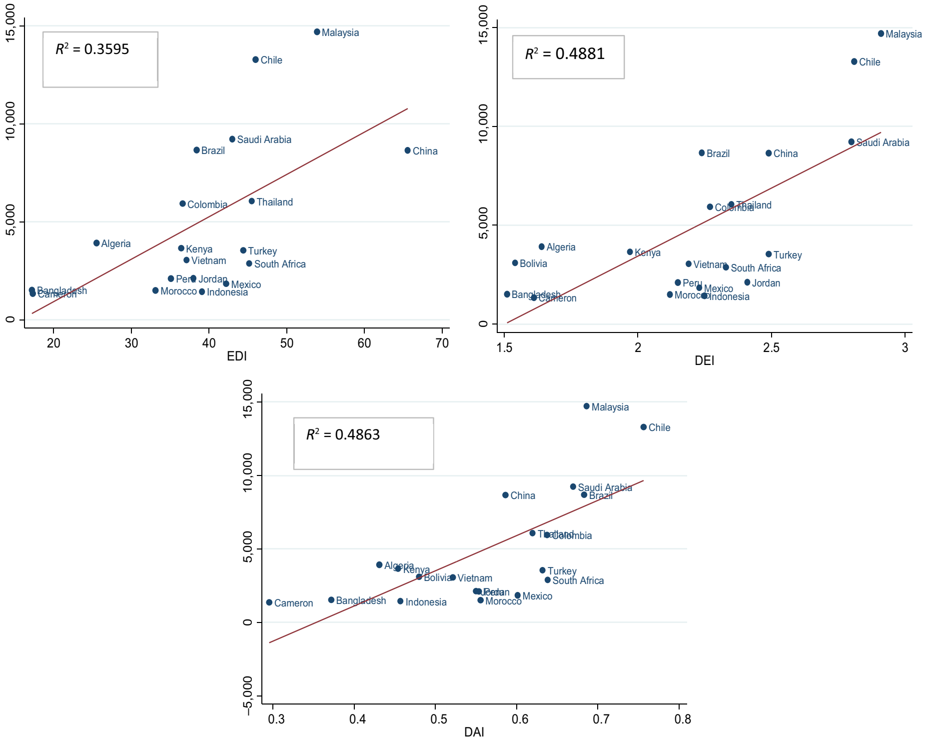


Figure 1.
Digital transformation indices and economic development (Per-capita GNI)

Source: Drawn by the author using data from World Bank Group (2016), Chakravorti and Chaturvedi (2017), Hermes (2018). DEI used for 2017, DAI for 2016, and EDI for 2018 – *most recent data for each index*

measures of digital transformation is worth noting. Despite the differences in the method of calculating the indices, and the dimensions that each cover, the relationship with the three of them indicate that countries with higher levels of digital transformation, indeed enjoy a higher level of labor productivity. The ranking of the countries is also close to the previous figure.

Figure 3 shows the relationship between the selected digital transformation indices and the employment rate inside the country. This relationship has been a point of wide debates in the literature regarding how possible would technology affect the available jobs inside the country. The various views have been presented in the previous section of literature review; data shall be able to confirm or refuse those views.

However, as the figure shows, no clear-cut conclusion can be driven from reviewing the relationship between digital transformation and employment. While the slope of both the DEI and EDI is positive, and the slope of DAI is negative, the very low goodness of fit doubts any result that can be obtained from those slopes. This suggests the existence of wide differences across the sample of countries in terms of how the stance of digital transformation affects the vacancies and employment opportunities inside the countries. Some countries such as Malaysia, Chile and China succeeded in converting the high levels of digital transformation into wider working opportunities. Digital transformation in some

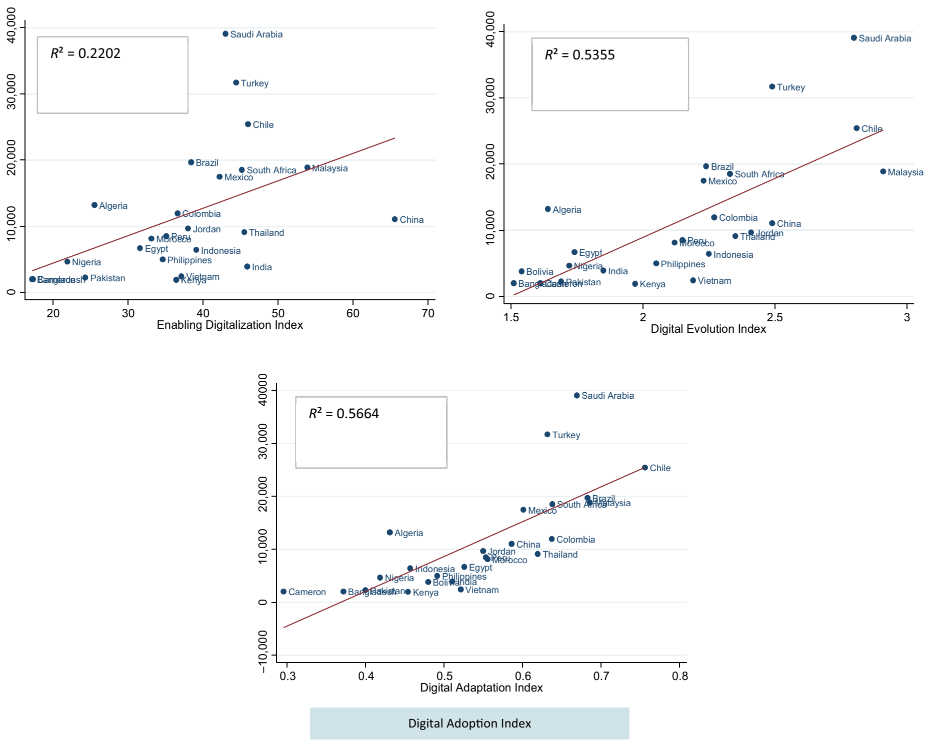


Figure 2. Digital transformation indices and labor productivity

Source: Drawn by the author using data from World Bank Group (2016), Chakravorti and Chaturvedi (2017), Hermes (2018). DEI used for 2017, DAI for 2016, and EDI for 2018 – *most recent data for each index*

other countries such as Turkey, South Africa and Jordan however did not generate the desired number of occupations.

An interesting addition to the DEI is a measurement of each country's current state of digital evolution and its pace of digital evolution over time, and then creating a *map of the digital planet*[2] (Chakravorti and Chaturvedi, 2017). Countries fall into four zones: Stand Out, Stall Out, Break Out and Watch Out, some countries are at the border of two zones. *Stand Out:* countries are highly digitally advanced and also move with high momentum; *Stall Out:* countries enjoy a high level of digital advancement while improving slowly; *Break Out:* countries with low scores of digital transformation but are evolving and improving rapidly; *Watch Out:* countries face significant challenges with their low state of digital transformation and low momentum. In selecting the sample of countries in this study, selection from the different zones was considered.

Figure 4 plots the DEI for the sample of developing countries for the year 2017 arranged ascending. The ranking of the countries as well as the classification of the digital planet map is consistent with the previous analysis; countries like Malaysia and China are in the Stand out region showing a rapid momentum of digital convergence and at the same time enjoying the associated merits of high economic development and productivity rates. Countries like

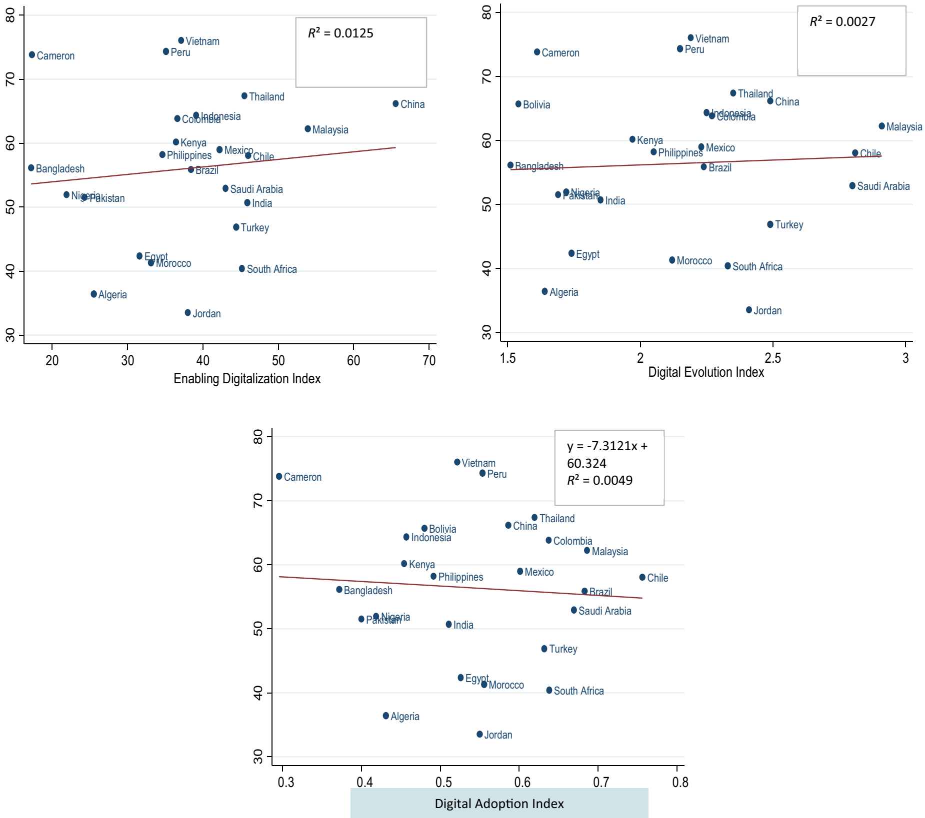
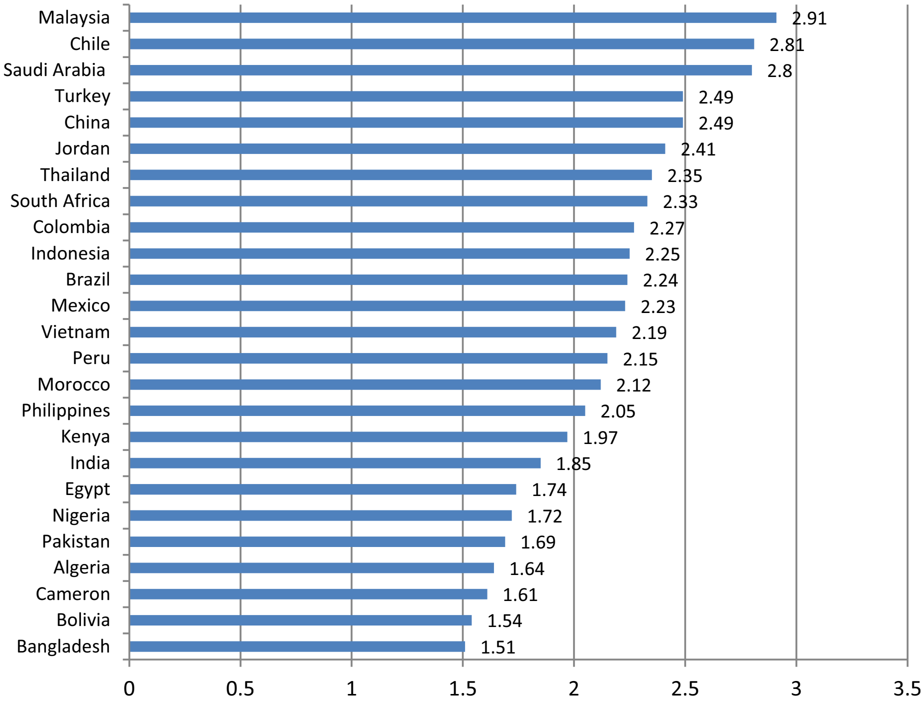


Figure 3.
Digital transformation indices and total employment

Source: Drawn by the author using data from World Bank Group (2016), Chakravorti and Chaturvedi (2017), Hermes (2018). DEI used for 2017, DAI for 2016, and EDI for 2018 – *most recent data for each index*

Egypt, Algeria and Nigeria are in the Watch out region, with many digital transformation challenges to face and yet more economic challenges to overcome.

To sum up, given the complexity of the DEI, its inclusion of both supply and demand sides of digital transformation using a large number of sub-indicators (170 indicator), and thus its diversified coverage of digital transformation's dimensions; it is recognized as of comparative advantage compared to the other indices of digital transformation. Together with its availability for developing countries, its better fit of the data (in terms of the higher R squared), and given the consistent results of the three indices; it was decided to rely on the DEI in the examination of the interrelationships in question. Moreover, DEI was not used in empirical research before, and this adds to the contribution of the paper and its originality. Therefore, in the coming section, DEI will be used as a proxy of digital transformation in the selected developing countries (which include countries in the four regions of the Digital Planet Map and hence allowing for diversified data) to study the relationship with economic development, labor productivity and employment.



Source: Drawn by the author using data from Chakravorti and Chaturvedi (2017)

Figure 4. Digital evolution index in selected developing countries

4.2 Model specification and data description

The paper follows the underlying set of equations adopted by Evangelista *et al.* (2014) but with some variations to suit the objective of the paper. While the previous model used different indices of digital transformation – each to reflect a different aspect, the paper chose to rely on a single composite measure which in itself captures different dimensions of digital: the *DEI*[3]. The estimated equations are as follows:

$$lprod = HCI + INV + DEI \quad (1)$$

$$GNIcapita = HCI + INV + POP + DEI \quad (2)$$

$$EMP = Lcost + RGDP + POP + DEI \quad (3)$$

$$VEMP = Lcost + RGDP + POP + DEI \quad (4)$$

The first equation examines the relationship between digital transformation and labor productivity (measured as the ratio between Real GDP and the number of employees inside the country). The second equation examines the relationship with economic development (measured by GNI per capita), the third equation studies the relationship with the employment rate (measured by the proportion of a country's population that is employed-total/male/female), while the fourth one examines it with vulnerable employment (measured by the proportion of vulnerable employment out of employment- total/male/female). A set of control variables are used in each equation which are the Human Capital Index, Investment (measured the ratio of Gross fixed Capital Formation to GDP), total population, labor cost (measured as the percentage of total compensation of employees to total expenses), Vulnerable employment and real GDP. RGDP, GNIcapita and POP are measured in logarithms. Educational attainment is a relevant factor that could influence the absorption of digital transformation inside the different developing economies, however, due to the non-availability of a single educational attainment variable that could be compared across the sampled countries; human capital was used instead to reflect the level of human development inside the country.

All data are collected from World Development Indicators except the DEI. Table 1 shows the summary statistics for those variables.

The four equations are estimated twice, first with robust ordinary least squares (OLS), and second with feasible generalized least squares (FGLS). FGLS is used to account for the expected correlation between the residuals in the regression model, In FGLS, modeling proceeds in two stages:

(1) The model is estimated by OLS, and the residuals are used to build a consistent estimator of the errors covariance matrix.

(2) Using the consistent estimator of the covariance matrix of the errors to implement GLS. FGLS is expected to show more reliable results.

4.3 Results and implications

Table 2 presents the results of both models as follows:

Many interesting results can be obtained from this table. First, concerning the relationship with labor productivity; the relation is positive and significant as suggested by the literature. Digital transformation as an adjacent consequence to technological breakthroughs is expected to boost efficiency, innovation, profitability and productivity. This result is of particular importance to developing countries which still have great potentials for increasing labor productivity. Instead of relying on old-fashion, high-cost, traditional and time-consuming outdated technology, by allowing for the new advances of AI, cost, time and effort could be saved and the result is higher labor productivity.

Second, concerning the relationship with economic development; again, the result is positive and significant and consistent with the literature. Higher degrees of digital transformation are associated with higher levels of per capita GNI. This further supports the previous result; digital transformation increases productivity and this in turn increases economic development. The benefits of converging digital transformation are reduced transaction costs, increased productivity and a positive contribution to economic development. Results obtained so far are highly consistent with the analysis of both the literature review and the descriptive analysis of the three compared digital transformation indices.

One of the controversial impacts of digital transformation is its relation to employment and job creation. The literature has shown mixed results with the majority confirming the impact of digital transformation on changing the composition and structure of jobs inside the economy. However, less evidence has been achieved regarding the impact on the total level of employment. The results of the FGLS model indicate a positive contribution of digital transformation toward employment rate in the developing countries. The higher the

Table 1. Summary statistics

Variable	Definition	Mean	SD	Minimum	Maximum
lprod	Labor productivity measured as the ratio between real GDP and number of employees inside the country	11329.03	9781.657	1923.612	39087.2
hci	Human capital index	0.542	0.093897	0.34	0.67
inv	Percentage of fixed capital formation to GDP	25.27408	8.419905	15.03563	48.39812
percapitagni	Per capita GNI	6124.643	4627.592	1340	19990
pop	Population	1.89E + 08	3.60E + 08	9779173	1.39E + 09
employ_ilo	Proportion of a country's population that is employed	56.36768	11.68185	33.513	76.035
memploy_ilo	Proportion of a country's male population that is employed	70.90216	9.098473	46.664	81.641
femploy_ilo	Proportion of a country's female population that is employed	41.43636	18.37635	10.733	71.454
mvuln	Vulnerable employment, male (% of male employment) (modeled ILO estimate)	38.28972	19.19842	3.264	76.154
fvuln	Vulnerable employment, female (% of female employment) (modeled ILO estimate)	46.27524	24.88864	1.151	85.219
vuln	Vulnerable employment, total (% of total employment)	41.31256	21.04739	2.96	78.483
rgdp	Real GDP	9.40E + 11	2.03E + 12	2.79E + 10	1.01E + 13
lcost	Labor cost measured as total compensation of employees as a percentage of total expenses - most recent figure	27.21018	15.0619	4.639944	58.16918
dei	Digital evolution index	2.1344	0.401695	1.51	2.91

Table 2.
Regression results

Independent variables	Robust ordinary least squares (OLS) Coef.	*p*-value	Feasible GLS (FGLS) Coef.	*p*-value
Equation (1). *Dependent Variable: labor productivity*				
Human Capital Index (HCI)	−9642.861	0.572	−4884.162	0.658
Investment	104.4128	0.607	−8.317466	0.953
Digital Evolution Index (DEI)	19032.87	0.001***	18990.47	0.000***
Constant	−26707.24	0.004***		
Weights			−26471.72	0.000***
Equation (2). *Dependent Variable: log Per capita GNI*				
Human Capital Index (HCI)	1.726857	0.142	1.142373	0.409
Investment	0.0034545	0.792	−0.0001841	0.987
Log Population	−0.0117252	0.05763*	0.0041507	0.935
DEI	1.319593	0.002***	1.450012	0.001***
Constant	4.722352	0.000		
Weights			4.581438	0.000**
Equation (3). *Dependent Variable: Employment rate*				
Labor cost	−0.1806375	0.374	−0.1166276	0.336
Log Real GDP	−5.065997	0.330	−10.40436	0.016**
Log Population	−0.3929043	0.870	−0.2250237	0.909
Digital Evolution Index (DEI)	10.50348	0.341	28.26779	0.001***
Constant	88.42046	0.151		
Weights			90.79594	0.085**
Equation (4). *Dependent Variable: Vulnerable Employment*				
Labor cost	−0.1280957	0.608	−0.106873	0.627
Log Real GDP	−12.34068	0.031**	−15.4004	0.001***
Log Population	3.622302	0.215	4.218689	0.031***
DEI	−9.435915	0.507	−5.400603	0.623
Constant	102.4988	0.139		
Weights			108.6521	0.031***

Notes: Both the dependent and the independent variables in the FGLS model are weighted variables calculated using the weights obtained from the OLS. Those weights are then added as an explanatory variable in the FGLS model. *, ** and ***indicates 90, 95 and 99% confidence levels respectively

degree of digital transformation, the higher is the employment rate. It is interesting that this result held true for female employment, while it is not significant for male employment (results in the Appendix). This indicates that the increase in total employment comes from offering more opportunities towards the females.

This is an important result and could be justified by at least two reasons which are also consistent with the literature. First, many countries are eager to meet the ambitious goal of reducing the gender gap in labor market participation by 25% by the year 2025, and are being committed to implementing a set of policies to improve the quality of women's employment and the provision of support policies. Those policies are targeted toward enhancing the working conditions for the women especially the parenting ones. In this regard, digital transformation is viewed as a new tool for the economic empowerment of women and a contributor to greater gender equality (OECD, 2018). Second, the ongoing digital transformation will strengthen the position of women in the labor market. More flexible ways of working – including working from home – may make it easier to combine paid work with parenting responsibilities which are still more likely the women's responsibility. Therefore, women may benefit from increased flexibility in work, and this could result in giving new chances for women who were not able to work before, and hence eventually increasing the employment of females. Those effects were not found tangible for male workers who still in many countries, especially the developing ones, enjoy more employment rights compared to females.

Though the achieved result of the impact of digital transformation on employment could be seen as contrary to the common-held belief that robots shall replace humans; it has its own justification. While digital transformation could drive some jobs obsolete, it also has the potential to create new jobs; old traditional occupations vanish through time and new others replace them. Furthermore, it is still strongly believed that some occupations cannot be totally displaced by robots or machines which lack the human skills of flexibility, judgment and common sense.

Hence, the main challenge for the future is not just mass employment, but the structural change of this employment. The analysis in this paper is limited to the effects of digital transformation on the aggregate level of employment, what is missing is the impact upon the change in the pattern of available and newly created jobs. This is of vital importance and is an area of future research. In this regard, while the analysis of the descriptive analysis failed to show a significant relationship between digital transformation and employment, the results of the econometric analysis indicate a positive and a significant one. By taking into account the differences between countries in level of income, population and labor cost, the heterogeneity among countries showed that indeed the relationship could be positive due to the difference between the conditional (econometric) and unconditional (descriptive) relationship analyzed using both tools.

The fourth and the last relation derived from the analysis is the relationship between digital transformation and vulnerable employment. Vulnerable employment is often characterized by inadequate earnings, low productivity and difficult conditions of work that weaken workers' major rights. It is generally expected that those type of workers are the more likely to be replaced within the array of digital transformation, despite that the model did not find significant relationship. This indicates that digital transformation alone is not sufficient to affect vulnerable employment; rather, reduction of vulnerable employment is more related to enforcement of labor laws and regulations and prevalence of poverty and its pressures. Future further research is still needed to examine whether employees who are more likely to lack decent working conditions, adequate social security and rights are more prone to be deprived from the technological ecosystem inside the country. The results are also insignificant in case of both male and female vulnerable employment – results in the Appendix). Higher level of RGDP is expected to decrease vulnerable employment, while higher population shall increase it.

Several interesting implications could be derived from those results with particular relevance to the developing countries. The results of the econometric model suggest that, if developing countries come to exploit the merits of digital transformation, significant paybacks will return to the economy in terms of higher productivity, higher GNI per capita and higher employment rates. However, those gains are not priceless; many economists are concerned that AI will reduce jobs, increase inequality and reduce incomes. Such fears are particularly observed in the developing region, where rates of unemployment, especially among young people, are already high.

The solution in this case could encompass a policy mix of different elements including: First, policy makers should emphasize the tangible benefits of AI on the economy and the society as a whole; those benefits should be clearly stressed to encourage a more positive societal attitude toward AI's potentials. Second, policymakers need to actively address and anticipate the downsides of AI. Some groups will be affected disproportionately by these changes. To prevent negative repercussions, policymakers should identify the groups at high risk of displacement and create strategies that focus on reintegrating them into the economy. Third, what is also vital is the accommodation of the stance of technology with the existing level of resources; specially the human ones. By matching the adopted level of technology with the level of development inside the country, workers shall be able to benefit more, increase their productivity, increase output and improve the economy as a whole. Fourth, as the literature indicates, digital transformation is expected to change the pattern and structure of the labor market and of the available vacancies. As new jobs emerge, countries will have to learn to successfully integrate human intelligence with machine intelligence so they coexist in a two-way learning relationship.

The suggested policy mix is dependent on preparing the next generations for the future of AI. This requires a fundamental transformation in the *learning environment*, (both in schools and in business), in the *institutional framework* (the ease and flexibility of supportive regulations), in the *economic environment* (the matching between the new market requirements and supply and demand conditions). Technical skills will also be required to design and implement effective AI systems and gain expertise in many specialties including both social and professional skills.

5. Conclusion

This paper aimed to examine the relationship between digital transformation on one side and economic development, labor productivity and job employment on the other side. The paper used two approaches. The first is the descriptive analysis to compare between different indices of digital transformation and analyzing their relations to the selected macroeconomic variables in a group of developing countries. The choice of analyzing developing countries in particular has been done with the objective of adding to the existing literature, where the majority of the empirical studies showed wide interest in developed and emerging countries, with much less attention to developing ones. After settling on with the DEI as a proxy for digital transformation, the paper proceeded by adopting a FGLS method to estimate the relationship quantitatively.

The results showed a positive relationship between digital transformation and both economic development and labor productivity. The relationship with employment – though positive – should be taken with some caution given the diversity of the sampled countries and the unclear relation derived from the descriptive analysis. The possible increase in jobs – via digital transformation – is expected to come from offering more job employments for the women and hence increasing female employment; male employment however, is not significant. Moreover, the model did not reach a significant relationship with regard to the impact upon vulnerable employment (whether total, male or female); more evidence is still needed before it can be concluded whether digital transformation does affect vulnerable employment. Also, future research needs to be directed towards examining the impact of digital transformation on the structure of the labor markets and on new jobs creation.

Artificial intelligence, rapid technological advances and digital transformation hold with them massive benefits for the developing countries. However, to reap those benefits, significant challenges should be addressed effectively by the policymakers in those countries. Those challenges include the distributional impacts of AI, the need to create a new generation able to adapt and work with machine intelligence, allocating the right amount of funds to the right technical intensive sectors, and finally, generating the appropriate environment for digital market makers.

Notes

1. The selected countries are Algeria, Bolivia, Brazil, China, Chile, Colombia, Cameron, Bangladesh, Malaysia, Saudi Arabia, Turkey, Jordan, Thailand, South Africa, Indonesia, Mexico, Vitneam, Peru, Morocco, Kenya, India, Egypt, Nigeria, Pakistan, Philippines.
2. See https://sites.tufts.edu/digitalplanet/dei17/
3. The Digital Evolution Index is a joint project between The Fletcher School at Tufts University and Mastercard that traces the emergence of a "digital planet", how physical interactions – in different fields – are being displaced by digitally mediated ones.

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Appendix. Digital transformation and vulnerable employment

	Coef.	Robust std. err.	t	$p > t$	[95% Conf. interval]	
Weighted male employment						
Wlcost	−0.11262	0.119971	−0.94	0.359	−0.36211	0.136876
Wlrgdp	−2.86126	3.521985	−0.81	0.426	−10.1856	4.463114
Wdei	1.763946	6.764366	0.26	*0.797*	−12.3033	15.83121
W	94.28588	17.25389	5.46	0	58.40445	130.1673
Weighted female employment						
Wlcost	−0.49384	0.176187	−2.8	0.011	−0.86024	−0.12744
Wlrgdp	−9.01944	6.097762	−1.48	0.154	−21.7004	3.661549
Wdei	23.74237	9.989596	2.38	*0.027*	2.967866	44.51687
W	78.65808	41.01128	1.92	0.069	−6.62955	163.9457

Table A1. FGLS results for male and female employment

	Coef.	Robust std. err.	t	$p > t$	[95% Conf. interval]	
Weighted male vulnerable employment						
wlcost	−0.38537	0.129884	−2.97	0.007	−0.65548	−0.11526
wlrgdp	−14.2883	3.527645	−4.05	0.001	−21.6245	−6.95218
wdei	−0.5598	6.41708	−0.09	*0.931*	−13.9049	12.78525
w	169.4726	24.50127	6.92	0	118.5194	220.4257
Weighted female vulnerable employment						
wlcost	−0.36928	0.172055	−2.15	0.044	−0.72709	−0.01148
wlrgdp	−11.1485	4.506341	−2.47	0.022	−20.5199	−1.777
wdei	−7.09464	9.835753	−0.72	*0.479*	−27.5492	13.35993
w	156.5695	24.84519	6.3	0	104.9011	208.2379

Table A2. FGLS results for male and female vulnerable employment

Corresponding author
Heidi Aly can be contacted at: heidi.aly@feps.edu.eg