The economic impacts of digitalization through an extended input-output model: theory and application to Tunisia

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Abstract

The paper contributes to the existing literature related to the economics of technology adoption. It focuses on the impacts of digitalization on the economic growth through various channels, mainly via investment and total factor productivity. Firstly, we begin by extending the Input-Output (IO) model of Kratena (2019) to enable the simulations of the macroeconomic impacts of digitalization. Secondly, we apply the model to the Tunisian Economy. It is found that the three main priority sectors to digitalize in Tunisia are the public administration, the education, and the construction sectors. Their full digitalization costs 1.8% of the GDP over 2021-2026 and leads to the same gain in terms of GDP growth, and to the creation of about 23 000 jobs per year over the same period. Besides, from 2027 and beyond and under the (restrictive) assumption of no extensive growth of the digitalized sectors, the productivity gains leads to 0.4% additional GDP growth and to the destruction of jobs equivalent to 0.64% of the active population, yearly.

JEL Classification: O33; R15

Keywords: Digitalization; economic growth; employment; Tunisia.

I. Introduction

Digital technologies are contributing to the transformation of economies through three main drivers: (i) socioeconomic inclusion by cutting the transaction costs, (ii) competition and efficiency through improved operational processes and enhanced resources allocation, and (iii) innovation by leading to the emergence of new products and services, based on digital platforms and decentralized ledger technologies (Verhoef, et al., 2021; World Bank, 2016).

This paper ambitions to enrich the existing literature related to the economics of technology adoption, and particularly to the literature analysing the impact of digitalization on economic growth through various channels including investment and total factor productivity. As noted by Acemoglu and Restrepo (2018) one of the modelling techniques of the digitalization effects considered in the literature, consists in introducing it as an increase in the factor productivity. In this paper, we propose an original simulations methodology based on an augmented Input-Output model while taking into account the multiple channels through which the digitalization affects economic growth. To this end, we extend the theoretical framework of Kratena (2019) which models a Keynesian economy, where the multiple sectors of the economy are coupled. The model includes equations matching the gross output with final demand by government and households, as well as a labor market and wage setting equations.

The novel mechanism that we conceive in the current paper concerns the digitalization of the production sectors, that generates increases in the required digital transformation investments and leads to higher total factor productivity at the sectorial and the macroeconomic levels. As consequence, the disposable income increases, which in turn improves private consumption and aggregate production. However, beyond the direct effect of the initial digitalization investment, the benefiting production sectors' gains in productivity lead to lower intermediary consumption in goods and services (provided by other sectors). The decrease of the intermediary consumption exercises an opposite effect on the aggregate production. The combined effects might be positive or negative and their impact on the demand on the labor market and the unemployment level is not obvious. The wage rate adjusts accordingly and passes-through partially to the prices in the goods and services market.

The application of the model enables us to delve into the opportunity for a developing country like Tunisia to favour the digitalization of its economic sectors in order to improve its macroeconomic performance. There are mixed empirical results about the macroeconomic effects of digitalization in developing countries. This is due to the conjunction of various channels catalyzed by the adoption of digital technologies and the digitalization of firms. It is also due to the various empirical methodologies and the analyzed samples which are considered. From this perspective, our paper intends to contribute to this literature by departing from the firm level productivity-enhancing layer to analyze if it passes-through to the macroeconomic level, in the Tunisian context. This is possible through the augmented input-output methodology previously described.

In our knowledge only few papers considered this research question. For the Tunisian context, Ben Youssef and M'Henni (2004) analyses the impacts of the adoption of information and communication technologies (ICT) on the economic growth during the period 1995-1999. The methodology consists in econometrically estimating the significance of the stock of ICT capital in explaining the aggregate output. The results show that the positive effect of ICT adoption on growth passed only through the investment channel. During that period neither the total factor productivity channel, nor the other potential channels were active. Kallal et al. (2021) assesses the impact of ICT diffusion on economic growth in Tunisia from a sectorial perspective. The study constructs a sectorial ICT diffusion index measuring the share of ICT in the input of the various sectors. Estimating a panel ARDL model of sectorial value-added over the period 1997-2015, the paper confirms the positive long-term effect of ICT diffusion on the Tunisian economic growth.

Our results show that the three main priority sectors to digitalize in Tunisia are the public administration, education, and constructions sectors. Their full digitalization costs 1.8% of the GDP over 2021-2026 and leads to the same gain in terms of GDP growth, and to the creation of about 23 000 jobs per year over the same period. Besides, under the restrictive assumption of no extensive growth of these sectors, the productivity gains due to the digitalization leads to 0.4% additional GDP growth and to the destruction of jobs equivalent to 0.64% of the active population, yearly from 2027 and beyond

This article contains five main sections. In section II, we present a literature review on the macroeconomic impacts of digital technologies adoption in developing countries. Section III presents the proposed extended Input-Output model which can be used to simulate the macroeconomic impacts of digitizing the production sectors in a given economy. In section III, we apply the methodology to the Tunisian economy. Section IV presents the main results. Finally, section V concludes and provide some policy recommendations.

II. Review of the literature on the macroeconomic impacts of digitalization

Total factor productivity (TFP) improvement is the main driver of long-term per capita income growth (Aghion and Howitt, 2009). It is known that TFP improves through an increase in the production efficiency and technological progress (Grosskopf, 1993). An increase in the production efficiency corresponds to a more efficient use of existing production factors. Whereas, the technological progress enlarges the set of the production possibilities. In developing countries, TFP increase is more likely to be driven by an enhancing of the production efficiency, since technological progress is weak (Drine and Nabi, 2010; Cirera and Maloney, 2017). In this context, there is an emergent literature trying to delve into the impacts of digital-technology adoption on productivity, growth and employment in developing countries.

On the firm level, empirical studies are convergent regarding the positive relationship between digital technology adoption and total factor productivity as well as in relation to employment. Cusolito et al. (2020) analyses the TFP of manufacturing firms adopting digital technology in 82 developing economies over 2002–2019. The results show that digital technology adoption, learning by exporting, and managerial experience have positive effects on TFP. Hjort and Poulsen (2019) identifies a large positive effects of fast Internet adoption on firm-productivity and employment rates (especially for higher-skill workers) with little or no job displacement across space, when considering a sample of 12 African countries. Commander et al. (2011) finds a positive relationship between ICT capital and productivity for the manufacturing firms in Brazil and India. The paper also shows that poorer infrastructure quality and labor market policy are associated with lower levels of ICT adoption, while poorer infrastructure is also associated with lower returns to investment. Brambilla and Tortarolo (2018) explores the impact of ICT adoption on firm performance and labour in the Argentinian manufacturing sector. The results show that ICT adoption increases firm productivity and wages with heterogeneous effects across firms, being larger for initially high-productivity and high-skill firms. Besides, the increase in wages includes higher-skilled as well lower-skilled workers, a result interpreted by the authors as the consequence of existing productivity and rent-sharing mechanisms. A similar result comes from Dutz et al. (2018) which shows that the adoption of productivity-enhancing technologies benefited to all categories of workers (although biased towards skilled workers) in Argentina, Brazil, Chile, Colombia and Mexico. This positive jobs outcome is due to dominant effects of increased productivity and expanding output relatively to the substitution of workers for technology.

However, on the macroeconomic level, empirical studies on the relationship between digital technology adoption and economic growth in developing countries produced mixed results. Farhadi et al. (2012) finds a positive relationship between ICT adoption and economic growth for a sample of 159 countries over the period 2000 to 2009. The study also finds that the effect of ICT use on economic growth is higher in high income group rather than other groups. Niebel (2018) identifies a positive relationship between ICT capital and economic growth in developing and emerging countries undistinguishable with that prevailing in developed economies over the period 1995–2010. Sassi and Goaied (2013) confirms the existence of such a relationship for 17 Middle Eastern and North African countries during the period 1960–2009. However, Cheng et al. (2020) shows that the effect of ICT diffusion on economic growth is ambiguous in the middle and low-income countries during the period 2000-2015, with positive effects identified only for mobile growth.

III. An extended Input-Output framework for analyzing the macroeconomics impacts of digitalization

To analyze the macroeconomic impacts of digitizing the production sector, we adapt the Input-Output (IO) model developed by Kratena (2019) and calibrate it for the Tunisian economy. The basic input-output equation is given by:

$$X_t = A_t X_t + C_t + G_t^* + D_t^{\Delta} \quad (1)$$

Where X_t is a column vector representing the gross output by sector, A_t is the technical coefficient matrix, C_t is the private consumption along the Keynesian model, G_t^* an exogenous public final consumption, and D_t^{Δ} the additional consumption derived by investing in the digitizing of all or some of the production sectors.

III.1. Modeling the digitalization

The progress in digitizing the production sector (i) at period (t) is measured by a vector of discrete maturity index $m_i(t)$ belonging to [1,10] where the level 10 corresponds to a full digitalization. Therefore, the digital maturity of the entire economy at period (t), is captured through the vector $m(t) = \{m_i(t), i = 1,..., I\}^T$ at period (t). The progress in digitizing the economy by $\Delta m(t) = \{\Delta m_i(t), i = 1,...,I\}^T$ impacts the matrix as follows:

$$A_t^{\Delta} = A_t - M_t \quad (2)$$

Where I is the identity matrix and the matrix M_t defined by

$$M_{ij,t} = \frac{A_{ij,t}[\Delta m_i(t)][\Delta V_i^m]}{\sum_{j=1}^{I} A_{ij,t} X_{j,t}} \quad (3)$$

$\Delta m_i(t)$ measures the progress on the scale [1,10] in digitizing sector (i) at period (t). The term (ΔV_i^m) is an exogenous term capturing the direct effect (absolute increase) of a one-step digital transformation of sector (i) on its added-value. Therefore, in case the digital maturity of the production sector remains the same, the terms ($M_{ij,t}$) are nulls and we obtain $A_t^{\Delta} = A_t$. Using equations (1) and (2) and isolating row (i) it is straightforward to show using (3) also that the **direct** additional impact of a progress in digitizing sector (i) by $\Delta m_i(t)$ is given by :

$$\Delta X_{\mathbf{i,t}} = -\sum_{j=1}^{I} M_{ij,t} X_{\mathbf{j,t}} = -\Delta m_i(t)[\Delta V_i^m] \quad (4)$$

Isolating the investment costs of the digitalization which is captured in (1) through the vector D_t^{Δ}, equation (4) signifies that the progress in digitizing sector (i) by $\Delta m_i(t)$ reduced the intermediary consumption of the sector by $|\Delta X_{\mathbf{i,t}}|$ which contributes to the increase of its added-value. For simplicity, we assume that the digitalization cost of sector (j) corresponding to a maturity progress by $\Delta m_j(t)$ is proportional to its turnover:

$$D_{tj}^{\Delta} = \Delta m_j(t) \alpha X_{\mathbf{j,t}} \quad (5)$$

where $0 < \alpha \leq 0.1$ is a proportionality coefficient. The digitalization cost of a given sector (j) takes the form of intermediary consumption addressed to other sectors (i) in proportions $\delta_{i=1,..I}$ with $\sum_{i=1,..I} \delta_i = 1$. Hence, we have

$$D_t^{\Delta} = \left(\delta_i \sum_{j=1}^{I} \alpha \left(\Delta m_j(t) X_{\mathbf{j,t}} \right) \right)_{i=1...I}^T \quad (6)$$

III.2. The disposable income and private consumption

The disposable income Y_t^D of households is defined by the following equation:

$$Y_t^D = \ell X_t w_t f_t (1 - t_{hh}) + S_t X_t g_t (1 - t_{hh}) + Y_t^{D,oth} \tag{7}$$

Where ℓ is a row vector containing the employment per output coefficients, w_t is the industry wage rates, and f_t is an adjustment coefficient in case there is a difference between wages in the IO table and wages in National Accounts. The row vector S_t represents the operating surplus per unit of output. In order to capture the fact that only a fraction of the operating surplus enters the disposable income of households, as the remainder stays in the firms, a second adjustment factor g_t is introduced. The household taxes and transfers are considered through an average tax rate t_{hh} on disposable income. Hence, the term $\ell w_t f_t (1 - t_{hh}) X_t$ represents gross wages minus corresponding net taxes and minus social security contributions). Whereas, the second term $S_t g_t (1 - t_{hh}) X_t$ represents gross operating surplus accruing to households minus corresponding net taxes (including social security contributions). The last component of the disposable household income $Y_t^{D,oth}$ represents the net income from abroad, profit and rent income, and is exogenous in this model. The vector of private consumption C_t is derived from a Keynesian consumption with a fixed marginal propensity of consumption μ and depends on the domestic budget shares represented by the column vector H :

$$C_t = A\left(Y_t^D\right)^{\mu} H \tag{8}$$

III.3. Employment, wage and price setting

The total employment L_t is obtained as the product of the row vector of employment coefficients $\bar{\ell}$ with the equilibrium vector of real output (in volumes) X_t^r adjusted by the evolution of the wage rate from (t-1) to (t) as follows where the wage base is denoted by $\overline{w}$:

$$L_t = \frac{w_{t-1}}{0.5(\overline{w}) + 0.5(w_t)} \bar{\ell}\, X_t^r \tag{9}$$

The elements of X_t^r are derived by dividing the elements $X_t(i)$ of the output vector at current prices, by the corresponding output price $p_t(i)$. At each period, the bargaining about the new wages takes in account the unemployment rate as follows:

$$Ln(w_{t+1}) = B + \beta Ln(U_t) \tag{10}$$

Where $U_t = \left(\overline{L} - L_t\right)/\overline{L}$ represents the unemployment rate, $\overline{L}$ the exogenous labor force and $\beta < 0$ an elasticity parameter. The change in wages affects the output prices according to the following basic equation of the IO price model:

$$p_{t+1} = A_t p_{t+1} + \bar{\ell}\, w_{t+1} + s + t^q \tag{11}$$

Where the vector t^q represents taxes net subsidies per unit of output.

IV. Application to the Tunisian economy

In this section we apply the suggested framework to the Tunisian economy, and simulate the impacts of the digitalization on the economic growth and employment.

IV.1. The rationale for analyzing the digitalization impacts on the Tunisian economy

Tunisia in one of the developing countries which is leveraging on digital technologies to enhance the competiveness of its economy, to create more jobs for the graduated youth, and to improve the inclusiveness of its social safety nets (Nabi, 2019). The private sector plays an important role in the Tunisian economy by contributing to almost 75% of the GDP and 76.5% of the total employment. Nevertheless, the majority of Tunisian firms are suffering from decreasing productivity. The percentage of firms which invested in innovative products and services decreased from 28% in 2013 to 14% in 2019. This lower investment is correlated with higher deceleration of their productivity with a growth rate passing from -4.5% in 2013 to -5.1% in 2019 (World Bank, 2020). The weak dynamism of the private sector translates to low total factor productivity and capital accumulation at the aggregate level, thus contributing to the current macroeconomic weaknesses of Tunisia.

The digitalization is one possible driver that Tunisian firms shall catalyse to improve their productivity and performance. It would enable them to gain in efficiency through efficient coordination between business processes, and/or by creating additional customer value through enhancing user experiences (Verhoef, et al., 2021). Yet, a recent assessment of the digital maturity of the Tunisian private sector showed that it is still emergent compared to the international frontier, with a score of 2.3 on a scale of 1 to 5 - higher score- (MTCEN and World Bank, 2020). The constraints explaining the slow digital transformation of the Tunisian firms are multiple. The main constraints are the scarcity of digital competences, the weak access to digital infrastructure (broadband internet, performant IT systems, cloud computing, etc.), and the insufficient adoption of emergent technologies and platforms which translate to slow growth of the e-commerce and e-marketing. In order to alleviate these constraints, the private sector ecosystem emphasized the importance of setting a package of incentives, among which: (i) providing financial, tax and technical incentives to support the digitalization; (ii) adjusting the labour regulations in order to take into account the impact of digitalization; (iii) setting a regulatory framework ensuring the digital trust and the security of e-contracts (IACE, 2016).

IV.2. Data and basic assumptions

The fundamental information needed in this model is the IO tables that describes the sales and purchases relationships between producers and consumers within the economy. The data is obtained from Organization for Economic Cooperation and Development (OECD) data[1]. The base year of the model is 2010 but the digitalization is simulated to begin in

[1] When some data (such as the employment per sector) are not available in the OECD database, we extracted it from the Tunisian National Institute of Statistics database.

2021. Hence, in order to assess the macroeconomic impact, we projected the data to 2021. In the input-output table, the method used to extrapolate the data from the base year to target year is the RAS method which needs the annual growth rates of the various sectors' production. Since these data aren't available, we estimate it by calculating the average annual growth rate between the two periods where the production volumes are available.

We assume[2] that the cost of an increase by 1 in the maturity score of each sector is fixed to 6.25% of its annual sales. Second, we assume that these investments expenditures are benefiting to the following sectors with the in brackets proportions: Post and telecommunications (70%), R&D (20%), Machinery and equipments (5%), and Computer and electronic equipment (5%). Finally, for the financing scheme, we assume that 50% of the investment is financed with a tax increase and the remaining is financed through external debt.

IV.3. A Benchmark case: full digitalization of all the sectors

For a benchmarking exercise, we simulate the increase of the maturity score by 1 of all the sectors until full digitalization is completed by reaching the maximum score of 10. This process begins in 2021 and is completed by 2026. It is found that this requires a huge investment cost with an average of about 10% of the GDP per year. The impact is a yearly increase of the GDP by 10% over 2021-2026, as well as the creation of more than 130 000 job per year compared to a business as usual scenario.

This full digital transformation will result in the increase of the productivity of the various sectors. Consequently, this generates the decrease of the intermediate consumption and the increase of the value added. The results show that for 2027 and each subsequent year, there is a gain of 3.7 percentage point of GDP growth. This is accompanied by the loss of 72 000 jobs per year, due to the decrease of the intermediate consumption by unit of output. Of course, this result is obtained under the assumption that there is no subsequent extensive increase of the output due to the digitalization.

IV.4. Digitalization of the priority sectors

As previously mentioned, the full digitalization of all the sectors requires huge investment costs (10% of the GDP for each year during 2021-2026) which is clearly not feasible for a developing country. Therefore, we tried to select the three priority sectors to fully digitalize by considering a selection criterion the impact on the GDP growth. Table 1 represents the top 3 sectors having the highest impacts on the GDP growth:

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[2] This assumption is based on the authors' calculation which extrapolate an estimation made in the following report : PWC (2016) "2016 Global Industry 4.0 Survey," www.pwc.com/industry40

Table 1. The most impactful sectors

Sector	*Yearly investment cost over 2021-2026 (%GDP)*	*Yearly GDP growth beginning from over 2021-2026 (percentage point)*	*Yearly GDP growth beginning from 2027 (percentage point)*	*Yearly GDP growth beginning from over 2021-2026 (percentage point)*	*Yearly variation of the employment beginning from 2027*
Public administration[3]	0,65%	0,65%	0,26%	0,65%	-0,27%
Education	0,35%	0,35%	0,08%	0,35%	-0,24%
Construction	0,82%	0,82%	0,06%	0,82%	-0,13%

Source: The Authors based on the extended output-input model applied to the Tunisian economy

Therefore, the highest priority shall be given to the digitalization of the public administration which has the greatest impact on the GDP growth, followed by the education, construction sectors. Note that the full digitalization of these three sectors requires a yearly investment of 1.82% of GDP and leads to the same increase in the yearly GDP growth over the period 2021-2026. It will also lead to the creation of about 23 000 jobs per year over the same period. However, policy makers shall take into consideration that the digitalization of the public administration, education and construction sectors generate yearly jobs destruction with respectively, -0.27%, -.24% and -0.13% of the active population each year beginning from 2027 and beyond. The job loss is mainly driven by the increase of the labor productivity generated by the digital transformation of the sector.

V. Conclusion

This paper proposes an original simulation methodology based on an augmented Input-Output model, in order to take into account the multiple channels through which digitalization affects the economic activity. To this end, we extend the theoretical framework of Kratena (2019) by modeling the impact of digitalization on total factor productivity at the sectorial and the macroeconomic levels. Beyond the positive direct effect of the initial digitizing investment, the gain of productivity in the digitalized sectors reduces their intermediary consumption in goods and services which are provided by the other sectors. The decrease of the intermediary consumption exercises an opposite effect on the aggregate production. The combined effects might be positive or negative and their impacts on the demand on the labor market is not obvious.

In a second stage, the proposed methodology is applied to the Tunisian economy, to investigate the impact of digitalizing the Tunisian economic sectors. First, for each economic sector we associate a digital maturity score reflecting its stage of digital transformation. It is shown that the full digital transformation of all the economic sectors costs around 10% of the GDP per year over 2021-2026. The overall impact of this digitalization is an increase by 10% of the GDP each year and the creation of around 130 000 job per year over 2021-2026. From 2027 and beyond, the full digital transformation increases the GDP by 3.7% and destructs 72 000 jobs per year (given the restrictive assumption of no extensive growth of the digitalized economic sectors). Finally, it is shown

[3] Including the defence and social security public services.

that the three priority sectors to digitalize under the investment budget constraint, are per order of priority the public administration, education, and the construction sectors. It is recommended that the digitization of these sectors be accompanied by the implementation of social security safety nets in order to reduce the negative impacts in terms of jobs destruction, especially in the public administration.

Appendix

Table 2. The initial maturity of the Tunisian economic sectors in 2021 and the impact of an improvement of their digital maturity of 1 on a scale of 1 to 10.

Sector	**Initial Digital Maturity** $m_i(2021)$	$(\Delta V_i^m)/V_i^m$
Electricity	3,9	1,04%
Financial intermediation	5,2	2,86%
Mining and quarrying	5,4	0,03%
Food products, beverages and tobacco	4,5	2,37%
Textiles, textile products, leather and footwear	5,0	2,52%
Wood and products of wood and cork	4,9	0,82%
Pulp, paper, paper products, printing and publishing	4,9	0,82%
Coke, refined petroleum products and nuclear fuel	5,1	1,39%
Chemicals and chemical products	5,1	1,39%
Rubber and plastics products	4,9	0,82%
Other non-metallic mineral products	4,6	2,01%
Basic metals	4,6	2,01%
Fabricated metal products	4,6	2,01%
Machinery and equipment, nec	4,9	0,82%
Computer, Electronic and optical equipment	5,3	0,33%
Electrical machinery and apparatus, nec	5,3	0,33%
Motor vehicles, trailers and semi-trailers	4,9	0,82%
Other transport equipment	4,9	0,82%
Manufacturing nec; recycling	4,9	0,82%
Gas and water supply	3,9	1,04%
Construction	4,6	3,31%
Wholesale and retail trade; repairs	4,9	1,28%

Hotels and restaurants	4,8	3,71%
Transport and storage	5,0	1,94%
Post and telecommunications	4,7	0,32%
Agriculture, hunting, forestry and fishing	4,7	0,57%
Real estate activities	5,5	2,64%
Renting of machinery and equipment	5,5	2,64%
Computer and related activities	5,5	2,64%
R&D and other business activities	5,5	2,64%
Public administration and defence; compulsory social security	5,5	2,64%
Education	5,5	2,64%
Health and social work	5,5	2,64%
Other community, social and personal services	5,5	2,64%
Private households with employed persons	5,5	2,64%

Source: The authors based on IACE (2016)

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