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Total Factor Productivity Growth, Technological Progress and Technical Efficiency Changes: Productivity Change Dimensions in Tunisia

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Abstract

In this study, we use the stochastic frontier production approach to split the total productivity growth sources into technical progress and technical efficiency changes of the economic sectors in Tunisia between 1961 and 2014. Based on the sectors' evolution, the analysis is centred on the technological progress trend, the technical efficiency change, and the role of productivity change in the economic growth. The empirical results show that the production factors have a significant effect on productivity. The review of the total factor productivity growth sources reveals that the contribution of technological progress is the main source of this growth.

Keywords: total factor productivity, technical efficiency, technological progress, stochastic frontier production approach, Tunisian economy

JEL Classification Codes: C23, D24, L6

1. Introduction

The economic production theory has prepared an analytical framework for most of the research on productivity. This theory is based on the production function which sets a well-defined relationship between a maximum producible outputs vector and another of production factors. Both parametric and non-parametric historical studies defined the total factor productivity (TFP) growth as the change of the output level while controlling inputs (Sickles & Zelenyuk, 2019).

Productivity is a key driver for the generation of wealth and employment. Economic growth can therefore be considered as the result of the accumulation of physical and human capital - so more highly skilled jobs and more investment - and of course a quick productivity increase. Productivity focuses on the effectiveness with which people combine resources to produce goods and services.

By definition, the change in efficiency consists in applying adequately the technology in production. As for the concept of TFP, it is applied on productivity in the same way as the technological progress (TP) in the literature.

Many observers (Ghali & Rezgui, 2008; Ghali, 2012; Jouini, 2014) agree that the Tunisian economy is down and that the challenges are complex and numerous. Ahead all of these challenges, improving the overall productivity is crucial. It is worth stating that the repercussions of the political and economic conditions on productivity, considered a key factor in the proper functioning of the Tunisian national economy, are now more than obvious.

This article evaluates the Tunisian economy response to serious problems, generating its poor performance in creating quality jobs. The analysis also stresses the fact that the Tunisian economy suffers from limited structural changes and its performance is specifically led by a growing public sector. It also hints to the existence of important misrepresentations that led to an under allocation of resources, clearly noticeable through the below potential economic performance.

In this study, we try to decompose the Tunisian total factor productivity growth into technical progress, technical efficiency changes and scale elasticity effects using a stochastic frontier method covering the period 1961-2014. Moreover, we give some insights to understand the TFP growth of the Tunisian sub-sector industries.

The rest of this paper is structured as follows: section 2 presents the literature review on the TFP and its determinants. Section 3 deals with the TFP decomposition and the functional form of the assessment model. Section 4 reveals the results and the debates related to the approach. Finally, the last section presents our major conclusions.

2. Literature Review

Relying on Farrell's (1957) contribution to the production analysis, there has been a substantial, empirical and methodological interest centred on the concept of the frontier production function which defines the other frontiers of possible input-output combinations for any set of observations. Much of Farrell's study deals with the possibility of funding measures and explanations of the changes in the TFP of observations regarding the frontier. Therefore, the technical inefficiency (TIE) is conventionally defined as the amount by which TFP is measured as less than the production capacity relying on the best practice.

According to the "Solow residual approach", the technological progress (TP) is believed to be the unique TFP growth source. This growth may be defined as "the output growth residual following the labour and capital inputs contributions and subtracted from the overall output growth" (Gordon, 2012). Solow's approach assumes that along the production process, the economies work at a full technical efficiency (TE). However, the efficiency frontier concept is used to show inefficiencies.

The stochastic frontier production (SFP) approach is an alternative method that differs from the Solow residual approach. It presumes that firms do not make full use of the existing technology as many different factors may lead to an unavoidable TIE in production. Stochastic frontier helps decompose the TFP into technical efficiency changes (TEC) and technical progress change (TPC).

Since it was first decomposed into efficiency and technical changes by Nishimizu and Page (1982), the TFP has been applied to different datasets to investigate the productivity growth. In 1990, a Translog cost frontier was estimated by Bauer (1990) who used US airline industry data to split TFP growth into efficiency, TP and scale components.

In 2001, an SFP model was used by Kim and Han (2001) to decompose the TFP growth sources in the Korean manufacturing industry into TP, TEC, change in allocative efficiency (AE) and scale effects. Based on 1980-1994 data, the empirical results show that TFP growth was mainly enhanced by TPC, TEC which has a significant positive effect, and AE that has a negative effect. Specific instructions are therefore required to enhance productivity in each industry.

Liao et al. (2007) used a SFP approach to classify the manufacturing industries. They tried to examine the TFP growth for eight East Asian economies between 1963 and 1998 using both single and cross-country regressions. Their study is centred on the TP trend and TEC as well as the productivity change of economic growth. The empirical results revealed that the TFP accounts for an important rising part of the output growth in which a developing TEC plays a key role in TFP growth.

In 2008, Minh et al. (2008) used a non-parametric approach by dividing the TFP growth sources in three Vietnamese economic sectors into TP and TEC. On the other hand, Minh et al. (2010; 2012) attempted to decompose and to bring some insights to understand the TFP growth in the Vietnamese industries between 2003 and 2007 using a SFP approach.

In 2011, Mahamat (2011) applied a SFP model in the Canadian manufacturing industries to investigate the TFP growth sources. This factor has been the only most significant determinant of a nation's living standard over long periods.

In 2013, Shackleton (2013) examined the general contours of the TFP growth in the US economy since 1870. He underlined the contribution of the various technological innovations to the development of the various economic sectors. He also noticed a correlation between TFP growth and improvements in general health and welfare such as the increase of life expectancy.

Kumbhakar et al. (2014) applied a broad selection of these models relying on different heterogeneity, heteroskedasticity and TIE presumptions to a single dataset from Norwegian farmers for the period 2004-2008. They also created a new model that separates firm effects from persistent and residual TIE. They revealed that TE results quite depend on how TIE is modelled and interpreted.

3. Total Factor Productivity Decomposition and Functional Form

3.1. TFP Decomposition

Referring to Kumbhakar et al. (2014) and Helali and Kalai (2015), we can define the SFP function as the following:

$$y_{it} = \alpha + f(x_{it}, \beta, t).\exp(v_{it} - u_{it}) \tag{1}$$

where y_{it} is the log of output of the *i*th sector $(i = 1,...,N)$ in the *t*th time period $(t = 1,...,T)$; $f(x_{it}, \beta, t)$ is the production technology frontier; x_{it} is the vector of input (in log); β is the associated vector of technology parameters to be estimated; *t* a time trend index that serves as a proxy for technical change; v_{it} is the random noise component, showing the exogenous shocks, that can change the production; and $u_{it} \geq 0$ is the non-negative component of output-oriented TE. Applying the maximum likelihood (ML) approach, the error terms acquire the following distribution assumptions:

$$u_i \sim N(0, \sigma^2) \text{ or } u_i \sim N(\mu, \sigma^2) \text{ and } v_{it} \sim N(0, \sigma_v^2) \tag{2}$$

Taking global differentials $f(x_{it}, \beta, t)$ with respect to time:

$$\frac{d \ln f(x, \beta, t)}{dt} = \frac{\partial \ln f(x, \beta, t)}{\partial t} + \sum_j \frac{\partial \ln f(x, \beta, t)}{\partial x_j} . \frac{d x_j}{dt} = \text{TP} + \sum_j \varepsilon_j . \dot{x}_j \tag{3}$$

where the first and second terms on the right-hand side are the output elasticity of the frontier output with respect to time, defined as TP. The second term evaluates the input growth weighted by the output elasticities with respect to input *j*, $\varepsilon_j = \partial \ln f / \partial \ln x_j$. A dot over a variable indicates its change rate. The derivative logarithm of (**1**) relating to time *t* and using (**3**) is presented as:

$$\dot{y} = \text{TP} + \sum_j \varepsilon_j . \dot{x}_j + \frac{dv}{dt} - \frac{du}{dt} \tag{4}$$

On the basis of equation (4), the TFP growth may be presented as the sum of TPC and TEC.

3.2. Model Formulation

In this study, a SFP approach was used. The production of the economic sectors is considered to be the function of both capital and labour. Hence, the elements of the productivity change can be assessed through the SFP approach, whereas, the time varying production frontier can be specified through a Translog form as follows:

$$\ln y_{it} = \alpha_0 + \sum_j \alpha_j . \ln x_{jit} + \alpha_t . t + \frac{1}{2} \sum_j \sum_l \beta_{jl} . \ln x_{jit} . \ln x_{lit} . + \frac{1}{2} \beta_{tt} . t^2 + \sum_j \rho_{tj} . t . \ln x_{jit} + v_{it} - u_{it} \quad (5)$$

where $j, l = L, K$. In Equation (5), y_{it} designates the observed production, *t* represents the time variable and *x* are variable inputs, subscripts *j* and *l* index factors. The efficiency term, *u* showing the output loss caused by unit-specific TIE is always greater than or equal to zero and assumed to be independent of the random error, *v*, which is supposed to have the normal properties $\left(iid \quad N\left(0, \sigma_v^2\right)\right)$.

The distribution of TIE impacts, u_{it}, is supposed to be the non-negative truncation of the normal distribution, following Battese and Coelli (1992). It takes the following form:

$$u_{it} = u_i \times \eta_t = u_i \times \exp\left[-\eta(t - T)\right], \ t \in \tau(i) \quad (6)$$

Here, the unknown parameter η represents the rate of change in TIE, and the non-negative random variable u_i, is the TIE effect for the *i*th firm in the last year of the data set. It should be noted that specifying inefficiency as $u_{it} = u_i \times \eta_t$ in (6) is an alternative to use the panel feature of the data without using other firm impacts. Kumbhakar (1991) evaluated $\eta_t = \left[1 + \exp\left(b_1 . t + b_2 . t^2\right)\right]^{-1}$ so that η_t can be monotonically increasing (decreasing) or concave (convex) depending on the signs and magnitudes of b_1 and b_2.

As the estimates of TE are perceptive to the selection of distribution assumptions, we choose the truncated normal distribution of general specifications for one-sided error u_{it}, and half-normal distribution can be experienced by the Likelihood Ratio (LR) test. Given the evaluations of the equation (5) coefficients, the sector TE level at time *t* is presented as:

$$\text{TE}_{it} = \exp\left(u_{it}\right) \quad (7)$$

and TEC is the change in TE, and the rate of TP is defined by,

$$\text{TP}_{it} = \frac{\partial \ln f\left(x_{it}, t\right)}{\partial t} = \alpha_t + \beta_{tt} . t + \rho_{tL} . \ln L_{it} + \rho_{tK} . \ln K_{it} \quad (8)$$

where L_{it} and K_{it} represent capital and labour, respectively.

If the technical change is non-neutral, it may differ for other input vectors. Hence, the used proxy is the geometric mean between adjacent periods,

$$\text{TP}_{it} = \left[\left(1 + \frac{\partial \ln f(x_{it}, t)}{\partial t}\right) \times \left(1 + \frac{\partial \ln f(x_{it+1}, t+1)}{\partial (t+1)}\right)\right]^{1/2} - 1 \qquad (9)$$

The output elasticity regarding each factor is formulated as follows:

$$\varepsilon_i = \frac{\partial \ln y}{\partial \ln x_i} = \alpha_i + \beta_{ii} Lnx_i + \beta_{ij} Lnx_j + \rho_{ti} t, \ \forall\, i \neq j \qquad (10)$$

The above equations show the change rate in output due to a 1% change in production factors. They can be applied to get an evaluation of aggregate returns to scale (RTS). The scale elasticity (SE) is calculated as $\varepsilon = \varepsilon_K + \varepsilon_L$. If the SE is a unity, then technology shows unchanged RTS.

4. Empirical Analysis

4.1. Data Issues

The panel data of the Tunisian economic sectors annual time-series during 1961-2014 are used in estimate production functions. The sectors and their sub-sector classification numbers are listed as following: In Tunisia, we have five main sectors of the Global Economy (GE) and five sub-sectors: Agriculture & Fishing (AF), Manufacturing Industries (MI), Non-Manufacturing Industries (NMI), Market Services (MS) and Non-Market Services (NMS).

The Manufacturing Industries have six sub-sectors: Agricultural & Food Industries (AFI), Building Materials, Ceramics & Glass (BMCG), Mechanical & Electrical Industries (MEI), Chemical Industries (CHI), Textiles, Clothing & Leather (TCL) and Various Manufacturing Industries (VMI). Moreover, the Non-Manufacturing Industries field has five sub-sectors: Mines (MIN), Hydrocarbons (HYDR), Water (WAT) and Building & Civil Engineering (BCE). Finally, the Market Services have four sub-sectors: Transport & Telecommunications (TT), Hotels, Cafes & Restaurants (HCR), Trade (TRD), and Other Market Services (OMS).

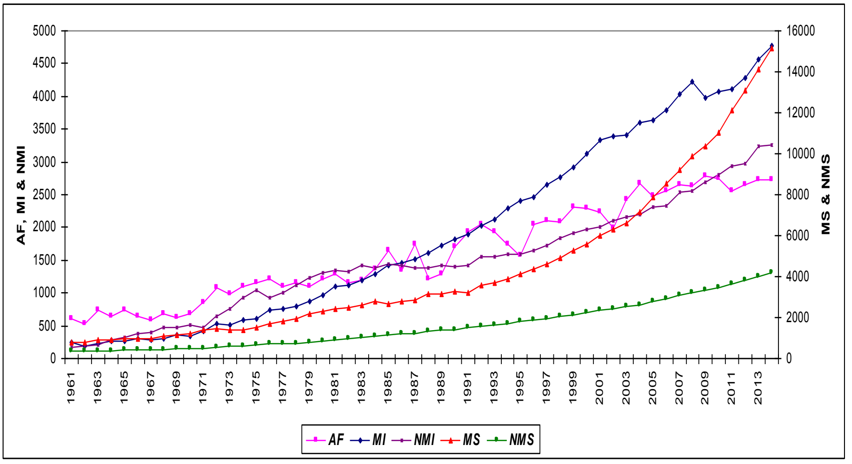

Figure 1: Production Evolution of the Sectors

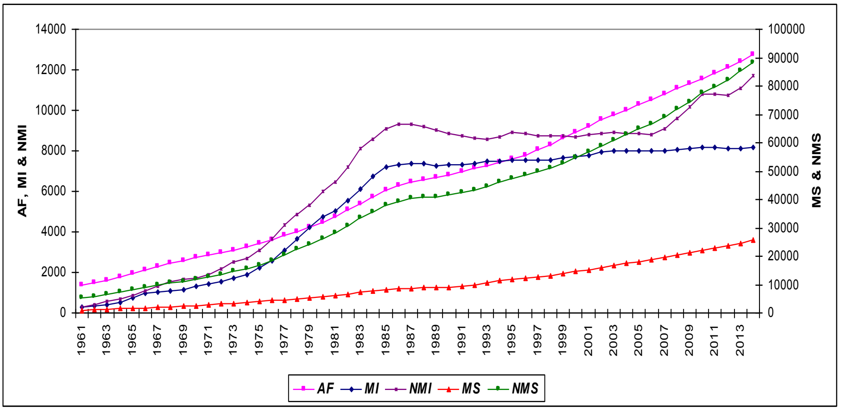

Figure 2: Capital Evolution of the Sectors

Production in these sectors is measured by the gross domestic product (GDP, volume in million Dinars, MD, at constant prices in 1990). Therefore, we can identify the substitution elasticity of labor and capital. To achieve this estimate, we use the statistical data provided by the Tunisian Institute of Competitiveness and Quantitative Studies (TICQS, 2012) for the period 1961-2014. Using this source, we could have relevant data to the capital stocks (volume in million Dinars, MD, at constant prices in 1990) and the employed population (in thousands).

Table 1: Variables Descriptive Analysis

	GDP					Capital					Labor				
	AF	**MI**	**NMI**	**MS**	**NMS**	**AF**	**MI**	**NMI**	**MS**	**NMS**	**AF**	**MI**	**NMI**	**MS**	**NMS**
Min	534.0	180.9	176.6	759.0	339.6	1369.9	299.4	297.4	989.1	5210.9	103.0	67.2	165.2	179.3	138.7
Max	2791.7	4775.9	3253.5	15162.7	4171.5	12726.8	8174.4	11689.9	25646.0	88304.4	389.0	556.7	483.0	1192.9	611.2
Avg	1614.6	1918.7	1475.4	4363.9	1578.6	6427.1	5373.4	6593.0	10010.2	39209.8	202.8	256.9	264.2	517.3	342.5
S-D	730.4	1440.9	829.8	3757.4	1106.2	3392.1	2967.5	3549.3	7157.6	24146.3	68.6	169.5	88.7	314.3	151.1
GG %	345.6	1890.8	1742.6	1897.6	1128.3	829.0	2630.3	3830.1	2492.9	1594.6	-49.0	728.6	192.3	565.4	340.6
AG %	2.8	5.6	5.4	5.6	4.7	4.1	6.2	6.9	6.1	5.3	-1.2	3.9	2.0	3.5	2.7

Note: Min: minimum, Max: maximum, Avg: average, S-D: standard deviation, GG: global growth rate, AG: average annual growth rate.
Source: Database of the Tunisian Institute of Competitiveness and Quantitative Studies, 2016.

Figures 1 and 2 show the capital and production evolution of the Tunisian economic sectors. Clear upward trend series with some phases of breaking in are easily noticed. The descriptive analysis of Table 1 proves this inference. In fact, we generally observe two different phases; the first corresponds to a low growth (1961-1986), especially, for the NMS and MS sectors, and the second (1987-2014) is characterized by a high growth in its upgrading period. Furthermore, a decrease in the capital stock was observed from the mid-90s for AF, MI and NMI, with the exception of the MS and the NMS which witnessed an important growth.

4.2. Hypotheses Tests and Model Selection

The parameters estimation in the SFP model given by Equation (**5**) is carried out via the ML method, using the STATA software. Two types of panels are constructed; the Global Economic sector panel used in the single regression consisting of a global sample and three sub-manufacturing sectors, and the panel data used in the regression. The associated parameters with v_{it} and u_{it} are:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \text{ and } \gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right) \tag{11}$$

These are associated with the stochastic term variances in the production function, v_{it} and the inefficiency term u_{it}. Parameter γ must be between zero and one. If hypothesis $\gamma = 1$ is established, it means that σ_u^2 is zero and thus the efficiency error term v_{it} is eliminated from the model leading to estimating the model parameters by the ordinary least squares (OLS). However, if the value of γ is one, we have the full-frontier model where the stochastic term does not exist in the model. We achieved a number of LR tests to recognize the suitable functional form and existence of inefficiency. Different hypotheses were examined among which the non-presence of TIE impacts are tested via the generalized LR statistics λ, obtained by:

$$\lambda = -2\left[\ln\{L(H_0)\} - \ln\{L(H_1)\}\right] \tag{12}$$

where $L(H_0)$ designates the quantity of the likelihood function of the frontier model in which the parameter restrictions specified by the null hypothesis H_0 are imposed and $L(H_1)$ designates the quantity of the likelihood function of the general frontier model. If the null hypothesis holds, then λ has approximately a mixed Chi-Squared distribution with degrees of freedom that are equal to the gap between the number of estimated parameters under H_1 and H_0, respectively.

4.3. Aggregated Samples Hypothesis Tests

Table 2 displays the test results of different null hypotheses on the total sample. The first null hypothesis suggesting that technology in the Tunisian economy is a Cobb-Douglas, $H_0: \beta_{LL} = \beta_{KK} = \beta_{KL} = \beta_{tt} = \rho_{tL} = \rho_{tK} = 0$, is not accepted for the global sample and all the aggregated samples. Thus, the Cobb-Douglas production function is not an adequate specification for the Tunisian economic sectors. Therefore, the Translog production function is far better in describing its technology.

Table 2: Generalized Likelihood Ratio of Hypotheses for Parameters

Hypothesis	Log-likelihood value	Test statistics	Critical value 1%	Critical value 5%	Decision
Translog production function (*Time-varying decay model*) model under H_1					
GE	190.26	-	-	-	-
MI	83.17	-	-	-	-
NMI	-93.56	-	-	-	-
MS	136.39	-	-	-	-
Cobb-Douglas production function, H_0: all β_s and ρ_s are equal to zero ($df = 6$)					
GE	167.40	45.72	16.81	12.59	Reject
MI	13.80	138.74	16.81	12.59	Reject
NMI	-152.07	117.02	16.81	12.59	Reject
MS	31.28	210.23	16.81	12.59	Reject
No technical change, H_0: $\alpha_t = \rho_{tL} = \rho_{tK} = \beta_{tt} = 0$ ($df = 4$)					
GE	179.05	22.43	13.28	9.49	Reject
MI	72.23	21.88	13.28	9.49	Reject
NMI	-132.54	77.97	13.28	9.49	Reject
MS	24.83	223.13	13.28	9.49	Reject
Neutral technical progress, H_0: $\rho_{tL} = \rho_{tK} = 0$ ($df = 2$)					
GE	183.57	13.38	9.21	5.99	Reject
MI	72.66	21.02	9.21	5.99	Reject
NMI	-125.66	64.19	9.21	5.99	Reject
MS	100.12	72.55	9.21	5.99	Reject
No technical inefficiency, H_0: $\mu = \eta = \gamma = 0$ ($df = 3$)					
GE	145.49	89.54	10.501	7.045	Reject
MI	-100.24	366.82	10.501	7.045	Reject

Table 2: Generalized Likelihood Ratio of Hypotheses for Parameters

NMI	-111.76	36.39	10.501	7.045	Reject
MS	-5.49	283.79	10.501	7.045	Reject
Half-normal distribution of technical inefficiency, H_0: $\mu = 0$ (*df* = *1*)					
GE	190.25	0.00	6.63	3.84	Accept
MI	82.54	1.25	6.63	3.84	Accept
NMI	-99.81	12.50	6.63	3.84	Reject
MS	136.27	0.25	6.63	3.84	Accept
Time invariant technical inefficiency, H_0: $\eta = 0$ (*df* = *1*)					
GE	189.37	1.79	6.63	3.84	Accept
MI	-82.95	332.24	6.63	3.84	Reject
NMI	-111.24	35.36	6.63	3.84	Reject
MS	65.90	141.00	6.63	3.84	Reject

Note: The critical value for this test involving $\gamma = 0$ is obtained from Table 1 of Kodde and Palm (1986) page 1246

. The second null hypothesis stating that there is no technical change: $H_0 : \alpha_t = \rho_{tL} = \rho_{tK} = \beta_{tt} = 0$ is strongly not accepted by the data in all cases. This involves the existence of a TP given the specified production model.

The third null hypothesis which suggests that TP is neutral: $H_0 : \rho_{tL} = \rho_{tK} = 0$ is also strongly not accepted by the data in all cases. This implies the presence of non-neutral TP in the data set of these manufactories.

Taking into account the SFP model specification, a particular interest surges from testing the hypothesis of the non-presence of sector-level inefficiency expressed by $H_0 : \mu = \eta = \gamma = 0$. The fourth null hypothesis is strongly not accepted at 1% significance for all the samples, suggesting that the average production function is an inappropriate description of the aggregated models for all the cases. Moreover, it underestimates the actual frontier owing to the existence of TIE effects in all sectors.

The fifth null hypothesis, which specifies that TIE effects have half-normal distribution, $H_0 : \mu = 0$, against truncated normal distribution, is accepted, except for NMI, at 1% significance level for the total sample and all the sub-samples.

The final null hypothesis suggesting that TIE is time-invariant $H_0 : \eta = 0$ is strongly rejected for all the aggregate samples (MI, NMI and MS) at least at 1% significance. The GE is the only case that accepts the hypothesis.

4.4. Stochastic Production Functions Estimation

Considering the Translog frontier specifications with the time-invariant model for the GE and with time-varying inefficiency effects for all sub-sectors, the statistical tests results of the calculated coefficients and the favourite SFP models were selected and their parameters estimates are presented in Table **3**.

Table 3: Panel Estimation of SFP and TIE Model

Parameters	GE	MI	NMI	MS
α_0	-4.989*** (1.641)	9.889*** (0.637)	2.970* (1.622)	-1.070 (1.919)
α_K	0.467*** (0.103)	0.395*** (0.059)	0.321*** (0.121)	0.535*** (0.113)
α_L	0.755*** (0.176)	0.453*** (0.053)	0.708* (0.421)	0.815*** (0.059)
α_t	-0.083*** (0.026)	0.173*** (0.025)	0.058** (0.027)	-0.142*** (0.041)
β_{KK}	-0.088** (0.043)	0.184*** (0.044)	0.554*** (0.076)	-0.244** (0.101)
β_{LL}	-0.199*** (0.076)	0.057 (0.052)	0.279*** (0.055)	0.967*** (0.165)
β_{KL}	-0.081 (0.064)	0.236*** (0.027)	-0.150** (0.066)	-0.304*** (0.056)
β_{tt}	-0.2e^{-3} (0.2e^{-3})	0.9e^{-4} (0.4e^{-3})	0.006*** (0.5e^{-3})	0.001 (0.6e^{-3})
ρ_{tK}	0.006*** (0.002)	-0.021*** (0.004)	-0.033*** (0.004)	0.036*** (0.004)
ρ_{tL}	0.011*** (0.003)	-0.003 (0.04)	-0.004 (0.004)	-0.035*** (0.008)
σ^2	0.546*** (0.035)	0.094** (0.039)	0.117*** (0.011)	0.013*** (0.001)
γ	0.979*** (0.013)	0.685*** (0.133)	0.3e^{-7***} (0.7e-^{8})	0.049*** (0.005)
μ	0	0	-0.002*** (0.2e^{-4})	0
η	0	0.049*** (0.002)	0.274*** (0.043)	0.088*** (0.007)
Log-likelihood function	189.364	82.544	-93.559	136.268

Note: Standard errors are given in the parenthesis; *, **, *** significant at 10%, 5%, 1%.

The estimates of η are positive in all the cases. Almost all the variables coefficients in all the equations are statistically significant. A significant γ along with a positive and significant η designates the presence of TE that decreases over time.

4.5. Estimation of TE, RTS, TP and TFP

It is worth reminding that one of the objectives of this study is to analyze the decomposition of TFP in TP, TE and economies of scale. Table 4 shows the average TE in the Tunisian economy over the period 1961-2014. The TE estimates vary considerably, both across sectors and over time. The average TE is 60.5% for the total sample. The MS have the highest estimate, 97.2%. AF and MI, which have 65.8% and 64%, rank second and third, respectively. The NMI have a score of 49.6%, while the NMS have the lowest estimate, 26.1%.

Table 4: The Average Technical Efficiency for Tunisian Economy

Sectors	TE 1961	TE 1970	TE 1980	TE 1990	TE 2000	TE 2014	Average
AF	0.658	0.658	0.658	0.658	0.658	0.658	**65.8%**
MI	0.640	0.640	0.640	0.640	0.640	0.640	**64.0%**
AFI	0.899	0.934	0.958	0.974	0.984	0.990	**96.0%**
BMCG	0.030	0.104	0.249	0.425	0.591	0.724	**35.5%**
MEI	0.077	0.190	0.361	0.534	0.680	0.789	**44.6%**
CHI	0.016	0.071	0.196	0.367	0.540	0.684	**30.9%**
TCL	0.264	0.423	0.589	0.722	0.819	0.884	**63.2%**
VMI	0.061	0.164	0.329	0.505	0.657	0.772	**42.1%**
NMI	0.496	0.496	0.496	0.496	0.496	0.496	**49.6%**
MIN	0.921	0.993	1.000	1.000	1.000	1.000	**99.3%**
HYDR	0.131	0.840	0.989	0.999	1.000	1.000	**89.3%**
ELEC	0.732	0.973	0.998	1.000	1.000	1.000	**97.6%**
WAT	0.653	0.963	0.998	1.000	1.000	1.000	**96.8%**
BCE	0.237	0.883	0.992	0.999	1.000	1.000	**91.5%**
MS	0.972	0.972	0.972	0.972	0.972	0.972	**97.2%**
TT	0.155	0.430	0.706	0.866	0.942	0.976	**71.1%**
HCR	0.050	0.257	0.570	0.793	0.908	0.961	**61.6%**
TRD	0.930	0.967	0.986	0.994	0.998	0.999	**98.3%**
OMS	0.180	0.461	0.726	0.876	0.947	0.978	**72.7%**
NMS	0.261	0.261	0.261	0.261	0.261	0.261	**26.1%**
GE	**0.605**	**0.605**	**0.605**	**0.605**	**0.605**	**0.605**	**60.5%**

Note: TE represents technical efficiency.

Moreover, Table 4 presents the details of scores by sector. In fact, AFI have the highest estimate (96%) of efficiency scores in the MI. However, the CHI have the lowest estimate, 30.9%. In NMI, the MIN sector takes the first position, with 99.3%. Finally, the TRD has the highest score in the MS where the estimated scores range from 61.6% to 98.3%. The average TE for all the sectors improved throughout the sample period, and this regular amelioration trend is also remarked in almost all the sub-sectors between 1961 and 2014. Inversely, the unchanging average TE in the global sectors over time is due to the use of the time-invariant model.

Table 5 shows RTS for the Tunisian economy and its subsectors between 1961 and 2014. For the whole sample and almost all the sub-sectors, the estimates of RTS are less than the unity, except for the MI where an increase of RTS was noticed. RTSs remain less than the unity. Therefore, the Tunisian economy is characterised by a decrease of RTS. The NMS have the lowest estimate of RTS, 0.535. These low RTS values may explain the lowest estimate of TE and give a perfect idea of the non-performance of the Tunisian economy.

As for the economy of scale, the majority of the sectors are characterized by increasing RTS. However, this evolution, at an average rate of 81.5%, has been characterized by ups and downs. This is not surprising when considering the more than proportional increase in the partial capital elasticity rather than the decrease in the labor elasticity. From an economic standpoint, the impact of capital input is significantly higher than that of labor. The comparison displayed in Table 4 is evidence that the mean TE of sectors and sub-sectors is different from one sector to another all along the study period. On average, the MS technical efficiency in the total sample and sub-samples is higher than that of the other markets although its average RTS does not exceed 69.5%. The average TE level of the economy in general is only 60.5% due to the low RTS average, which is 81.5% (see Table 5).

The average annual rate estimates of change in efficiency for the Tunisian industrial sectors and sub-sectors are displayed in Table 6. These efficiency changes are calculated using Equation (**7**).

Table 5: The Average RTS for Tunisian Economy

Sectors	RTS 1961	RTS 1970	RTS 1980	RTS 1990	RTS 2000	RTS 2014	Average
AF	0.55	0.70	0.89	1.00	1.15	1.25	**93.8%**
MI	1.30	1.18	0.97	0.87	0.92	1.01	**101.0%**
AFI	0.936	0.821	0.896	0.987	0.903	1.028	**90.5%**
BMCG	1.066	0.793	1.087	1.079	0.950	1.125	**99.8%**
MEI	1.179	0.725	0.753	0.971	0.844	0.935	**87.0%**
CHI	1.160	1.104	0.736	0.882	1.009	1.162	**95.5%**
TCL	1.056	0.806	0.990	1.118	1.101	1.138	**103.3%**
VMI	1.135	0.864	0.609	0.712	0.829	0.980	**80.9%**
NMI	1.05	0.90	0.79	0.85	0.96	1.01	**89.7%**
MIN	1.148	0.526	0.818	0.966	1.163	1.113	**93.0%**
HYDR	1.150	1.075	0.711	1.123	1.041	1.142	**102.9%**
ELEC	1.120	0.587	0.903	1.135	1.045	1.184	**92.2%**
WAT	1.161	0.153	1.066	0.924	1.160	1.077	**89.1%**
BCE	1.170	1.101	1.166	1.106	1.131	1.064	**108.3%**
MS	0.82	0.77	0.71	0.67	0.64	0.63	**69.5%**
TT	1.111	0.956	1.184	1.018	0.921	1.100	**106.0%**
HCR	0.847	0.646	1.142	1.186	1.047	1.022	**96.6%**
TRD	0.705	1.116	1.127	1.040	0.910	1.165	**104.4%**
OMS	1.087	1.200	1.065	0.918	1.109	0.493	**108.0%**
NMS	0.61	0.56	0.50	0.50	0.54	0.59	**53.5%**
GE	**0.865**	**0.820**	**0.769**	**0.779**	**0.844**	**0.899**	**81.5%**

Note: RTS represents Returns to Scale. (Source: Author's calculations)

The estimate of the average growth rate of efficiency in the Tunisian economy and its sectors suggests that the level of efficiency has increased over the whole period, whereas the scores have fallen progressively over the years. For example, the BMCG and CHI, have average efficiency growth rates of 6.8% and 8%, respectively. These are the highest rates followed by HCR (about 6.5%) and MEI (about 4.9%). Moreover, AFI, MIN, and TRD recorded the lowest TEC, about 0.2%, 0.2% and 0.1%, respectively.

The annual TP change estimates for the Tunisian economy and its sub-sectors are shown in Table **6**. In terms of TE evolution, it is characterized by a decreasing effect and has a positive or null rate of change along the study period. The empirical analysis provides an average efficiency of about 60.5%. This can be interpreted by the fact that, on average, the Tunisian industries can increase their production with 39.5% using the same amount of inputs, but in a more optimal way.

Table 6: TEC in Tunisian Economy, 1961-2014

Sectors	1961-1962	1969-1970	1979-1980	1989-1990	1999-2000	2009-2014	1961-2014
AF	0.000	0.000	0.000	0.000	0.000	0.000	**0.0%**
MI	0.010	0.081	0.049	0.030	0.021	0.011	**3.4%**
AFI	0.005	0.003	0.002	0.001	0.001	0.000	**0.2%**
BMCG	0.181	0.119	0.072	0.044	0.027	0.016	**6.8%**
MEI	0.130	0.086	0.052	0.032	0.019	0.012	**4.9%**
CHI	0.215	0.141	0.085	0.051	0.031	0.019	**8.0%**
TCL	0.065	0.044	0.027	0.016	0.010	0.006	**2.5%**
VMI	0.142	0.094	0.057	0.035	0.021	0.013	**5.4%**
NMI	0.245	0.024	0.002	0.000	0.000	0.000	**4.5%**
MIN	0.019	0.002	0.000	0.000	0.000	0.000	**0.2%**
HYDR	0.620	0.056	0.004	0.000	0.000	0.000	**4.8%**
ELEC	0.074	0.009	0.001	0.000	0.000	0.000	**0.7%**
WAT	0.103	0.012	0.001	0.000	0.000	0.000	**0.9%**
BCE	0.406	0.040	0.003	0.000	0.000	0.000	**3.2%**
MS	0.155	0.073	0.029	0.012	0.005	0.002	**4.6%**
TT	0.171	0.081	0.033	0.013	0.006	0.002	**3.9%**
HCR	0.289	0.133	0.053	0.022	0.009	0.004	**6.5%**
TRD	0.006	0.003	0.001	0.001	0.000	0.000	**0.1%**
OMS	0.156	0.074	0.030	0.012	0.005	0.002	**3.6%**
NMS	0.000	0.000	0.000	0.000	0.000	0.000	**0.0%**
GE	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.0%**

Note: Source: Author's calculations

Table 7 shows a considerable variation among sectors. Indeed, AF recorded a negative TPC of 0.8%. In all the sectors of the MI, the TPC is negative and ranges from -1.5% to 0%. The same situation is observed in the NMI where the rates vary between -0.4% and -0.1%. In total, the Tunisian economy showed a decrease of TP over the study period. It appears from this table that the TP is an important component in the measurement of the TFP growth. In terms of the industries' behavior in respect to TP, we note that the rate is generally negative and on the decrease. This indicates that these sectors have lost a TP of 0.8% on average during the study period.

Table 7: TPC in Tunisian Economy, 1961-2014

Sectors	1961-1962	1969-1970	1979-1980	1989-1990	1999-2000	2009-2014	1961-2014
AF	-0.002	-0.033	0.008	-0.011	0.025	-0.011	**-0.8%**
MI	-0.023	0.038	0.012	0.023	0.001	0.003	**1.1%**
AFI	-0.049	-0.023	-0.009	0.009	-0.006	-0.025	**-1.3%**
BMCG	-0.019	-0.039	-0.019	0.011	0.013	0.006	**0.0%**
MEI	-0.010	-0.006	-0.008	-0.017	-0.022	-0.034	**-1.4%**
CHI	-0.048	-0.006	-0.014	0.006	-0.005	0.013	**-0.2%**
TCL	-0.006	-0.040	-0.034	-0.014	-0.007	-0.005	**-1.1%**
VMI	-0.010	-0.009	-0.005	-0.010	-0.015	-0.005	**-1.5%**
NMI	0.032	0.017	0.036	-0.009	-0.005	0.010	**1.2%**
MIN	-0.044	-0.048	-0.029	-0.011	0.010	0.045	**-0.2%**
HYDR	0.026	-0.039	-0.028	-0.012	0.008	0.005	**-0.1%**
ELEC	0.012	-0.026	0.018	-0.022	0.025	0.006	**-0.3%**
WAT	-0.034	-0.006	-0.006	-0.049	0.012	0.006	**-0.4%**
BCE	0.028	-0.007	-0.007	-0.006	0.012	0.005	**-0.3%**
MS	0.007	0.036	0.022	0.021	0.022	0.013	**2.2%**
TT	-0.035	-0.014	0.017	0.021	0.005	0.021	**1.1%**
HCR	-0.034	0.047	-0.041	-0.005	0.017	0.010	**0.0%**
TRD	-0.013	0.036	-0.013	0.023	0.038	0.040	**0.1%**
OMS	-0.041	-0.017	0.048	0.007	0.006	0.018	**0.6%**
NMS	0.035	0.017	0.017	0.003	0.006	0.004	**1.5%**
GE	**-0.002**	**-0.033**	**0.008**	**-0.011**	**0.025**	**-0.011**	**-0.8%**

Table 8 shows the average annual TFP growth for the Tunisian sectors and sub-sectors, where TFP growth in the majority of sectors and sub-sectors is positive, with an average TFP of about 4.5%, 6.8%, 3.6%, 7.8%, 1.4%, 3.8%, 5.7%, 0.0%, 4.7%, 0.3%, 0.5%, 2.9%, 6.8%, 5.0%, 6.5%, 0.2%, 4.2%, and 1.5% for MI, BMCG, MEI, CHI, TCL, VMI, NMI, MIN, HYDR, WAT, BCE, MS, TT, HCR, TRD, OMS and NMS, respectively. Given the specifications of the Translog SFP with a time-invariant model for the global sample, the average TFP growth is negative and so is the TPC.

As already seen, the TFP growth rates of the majority of the sectors have a positive effect due to the increase of both TEC and TPC between 1961 and 2014. However, the TFP growth rates of the total sample, AF and AFI have a negative effect due to the TPC. In general, the TFP in all the economic sectors decreased continuously throughout the sample period. As for the sub-sector estimates, they indicate that their main sectors grew fast during the sample period.

Table 8: TFP Growth in Tunisian Economy, 1961-2014

Sectors	1961-1962	1969-1970	1979-1980	1989-1990	1999-2000	2009-2014	1961-2014
AF	-0.002	-0.033	0.008	-0.011	0.025	-0.011	**-0.8%**
MI	-0.013	0.119	0.061	0.053	0.022	0.014	**4.5%**
AFI	-0.044	-0.020	-0.007	0.010	-0.005	-0.025	**-1.1%**
BMCG	0.162	0.080	0.053	0.055	0.040	0.022	**6.8%**
MEI	0.119	0.080	0.044	0.015	-0.003	-0.022	**3.6%**
CHI	0.167	0.136	0.071	0.057	0.026	0.033	**7.8%**
TCL	0.059	0.003	-0.007	0.003	0.003	0.001	**1.4%**
VMI	0.132	0.085	0.052	0.024	0.006	0.008	**3.8%**
NMI	0.277	0.041	0.038	-0.009	-0.005	0.010	**5.7%**
MIN	-0.025	-0.046	-0.029	-0.011	0.010	0.045	**0.0%**
HYDR	0.646	0.018	-0.025	-0.012	0.008	0.005	**4.7%**
ELEC	0.086	-0.017	0.019	-0.022	0.025	0.006	**0.3%**
WAT	0.069	0.006	-0.005	-0.049	0.012	0.006	**0.5%**
BCE	0.434	0.033	-0.005	-0.006	0.012	0.005	**2.9%**
MS	0.162	0.109	0.051	0.033	0.027	0.015	**6.8%**
TT	0.136	0.067	0.050	0.034	0.011	0.023	**5.0%**
HCR	0.255	0.180	0.012	0.016	0.026	0.014	**6.5%**
TRD	-0.007	0.039	-0.012	0.024	0.038	0.040	**0.2%**
OMS	0.115	0.057	0.078	0.020	0.012	0.020	**4.2%**
NMS	0.035	0.017	0.017	0.003	0.006	0.004	**1.5%**
GE	-0.002	-0.033	0.008	-0.011	0.025	-0.011	**-0.8%**

Variations in TE at the sectoral level are attributable to problems of investment planning and utilization, lack of technical experience, poor management and organisation, particularly in co-ordinating intermediate input supply, in addition to the general impact of stabilisation policies. The three sectors (AF, NMI, and NMS), where these problems were particularly acute, showed rapid decline rates in the level of TE during the study period. Five manufacturing sectors out of six, which are characterised by a general improvement level of TE (BMCG, MEI, CHI, TCL and VMI), reflect, to some extent, the success of the explicit political actions undertaken to improve the technical information diffusion, project implementation, and input supplies co-ordination.

Table 9 summarizes the results of the relationship estimates which measure the average elasticity of output factors and the scale for the different industrial sectors over the 1961-2014 period. In general, the labor elasticity is lower than that of the capital where we recorded a considerable decrease in elasticity of about 1.3 between 1961 and 2014.

In addition, for most sectors, except for NMS, the SE is greater than 1. This can be explained by the fact that different sectors are capital intensive, stimulating sectors to exploit the productivity gains from the substitution of labor by capital.

Table 9: The Output Average Elasticity by Industry, 1961-2014

Sectors	Labour elasticity			Capital elasticity			Scale elasticity		
	1961	2014	Average	1961	2014	Average	1961	2014	Average
AF	0.61	0.37	0.46	0.91	0.77	0.82	1.52	1.13	1.28
MI	0.79	0.41	0.50	1.01	0.79	0.84	1.80	1.20	1.34
NMI	0.79	0.37	0.47	1.01	0.77	0.83	1.80	1.15	1.30
MS	0.65	0.29	0.43	0.93	0.73	0.81	1.58	1.02	1.24
NMS	0.46	0.14	0.26	0.82	0.64	0.71	1.28	0.78	0.97
GE	0.66	0.32	0.43	0.92	0.74	0.80	1.60	1.05	1.23

This observation is further confirmed when analyzing the capital-labor relationship in terms of partial elasticity. In this case, the impact of the change in the labor share in a given category is variable. Indeed, the Translog specification allows an evaluation of each sector given that this effect depends on the different qualification structures.

According to a survey on the various sources of growth in Tunisia over more than a quarter of a century prepared by TICQS (2014), the relatively moderate rate of growth recorded in the period in certain countries is attributed mainly to a rate of a productivity growth. Such a growth remains insufficient, despite its acceleration over the previous period. The decomposition of labor productivity growth between capital intensity and TFP shows a deficit in capital intensity resulting in a lack of capital available per worker due to insufficient capital accumulation. The acceleration in the growth rate of the sectoral labor productivity requires a rethinking about the investment policy.

At the aggregate level, if we look at the explanation of the decomposition of productivity of the global economy, it could increase via two factors. The first is to accelerate the pace of intra-industry productivity growth, and in this case, we join the above set out recommendations related to an acceleration of investment. The second factor evaluates the extent of the contribution of the structural change in Tunisia to accelerating the TFP growth of the whole economy over the period spanning between 1961 and 2014. However, it shows a rigid effect whether in terms of reallocation of labor or that of production. The question that arises here is how to force a structural change?

In summary, the Tunisian economy is affected by a pathetically low productivity, some distortions and resources misallocation. While most upper and middle income countries have experienced economic takeoff during the previous years, Tunisia has been hampered by the inability to adapt its growth model. An analysis of the GDP growth breakdown highlights that Tunisia's growth over the past two decades has been largely facilitated by an accumulation of factors, with only a little contribution resulting from gains in TFP.

The new model should discard privileges, open up economic opportunities for all Tunisians and increase prosperity across the country. This requires abandoning the idea of a welfare state, which helped give rise to patronage and privilege in favor of the elites. As signaled by Achy (2011), African Development Bank (2013), World Bank (2014) and Jouini (2014), it had better move to a system where the state works to establish and enforce fair rules promoting the individual initiative and providing a targeted and effective support to the most disadvantaged.

5. Conclusions

The major results of this study we came up with, clearly show that TFP decomposition is relevant. Concerning the efficiency estimations, the average annual TEC in the Tunisian economy is absent because the null hypothesis, which states that TE is time-invariant, can be accepted. However, for all the other sectors, the average annual TEC is positive. The most important assessment is that of the TFP growth which is estimated at 0.8%. In addition, TFP recorded the fastest growth in both service markets and non-manufacturing industries. In the former sector, it recorded an annual growth of 6.8%, whereas in the latter, it rose to 5.7%. On the other hand, in the MI, TFP growth was estimated at 4.5%. According to the obtained results, we can see that, although productivity growth was enhanced by TP, it was positively affected by the TEC.

If we take the case of Tunisia whose economy largely depends on foreign technology, its failure in using this technology in compliance with the international standards may doom it to be unable to have a technical progress. For example, the Tunisian manufacturing sector showed no clear frontier change along the 1961-2014 period. Furthermore, we can say that the slowdown of the TFP growth is due to both the decline of a TP rate and the collapse of a TE. Therefore, the magnitude of both of them implies that the decline of the TP clearly influences the TE. Actually, the sudden change in the TP pattern shows that there is an important change in the production environment during the study period.

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Reference

Achy, L. (2011). *Tunisia's Economic challenges* (Vol. 2011, pp. 1-28). Washington, DC: Carnegie Endowment for International Peace.

African Development Bank. (2013). *Towards a new economic model for Tunisia, identifying Tunisia's binding constraints to broad based growth.* African Development Bank, Government of Tunisia. Retrieved from https://www.afdb.org/en/documents/document/towards-a-new-economic-model-for-tunisia-identifying-tunisias-binding-constraints-to-broad-based-growth-31216.

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis, 3*(1-2), 153–169. https://doi.org/10.1007/BF00158774.

Bauer, P. W. (1990). Decomposing TFP growth in the presence of cost inefficiency, non-constant returns to scale, and technological progress. *Journal of Productivity Analysis, 1*(4), 287-299. https://doi.org/10.1007/BF00160047.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*: Series A (General), *120*(3), 253-281. https://doi.org/10.2307/2343100.

Ghali, S. (2012). *Tunisian exports' sophistication* (World Bank Middle East and North Africa Working Paper Series No. 54). World Bank. https://doi.org/10.2139/ssrn.2007687.

Ghali, S., & Rezgui, S. (2008). *FDI contribution to technical efficiency in the Tunisian manufacturing sector* (Working Paper No.421). Economic Research Forum.

Gordon, R. J., (2012). *Is U.S. economic growth over? Faltering innovation confronts the six headwinds* (NBER Working Paper No. 18315). National Bureau of Economic Research.

Helali, K., & Kalai, M. (2015). Technical efficiency determinants of the Tunisian manufacturing industry: stochastic production frontiers estimates on panel data. *Journal of Economic Development, 40*(2), 2-26.

Jouini, E. (2014). *Tunisie L'espoir: Mode d'emploi pour une reprise*. Tunis: Cérès éditions. Retrieved from https://www.webmanagercenter.com/2014/02/21/146620/publication-tunisie-l-espoir-mode-d-emploi-pour-une-reprise/

Kim, S., & Han, G. (2001). A decomposition of total factor productivity growth in Korean manufacturing industries: A stochastic frontier approach. *Journal of Productivity Analysis, 16*(3), 269-281. https://doi.org/10.1023/A:1012566812232.

Kodde, D. A., & Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica, Journal of the Econometric Society*, *54*(5), 1243-48.

Kumbhakar, S. C. (1991). Estimation of technical inefficiency in panel data models with firm-and time-specific effects. *Economics Letters,36*(1),43-48. https://doi.org/10.1016/0165-1765 (91) 90053-N.

Kumbhakar, S. C., Lien, G., & Hardaker J. B. (2014). Technical efficiency in competing panel data models: A study of Norwegian grain farming. *Journal of Productivity Analysis, 41*, 321-337. https://doi.org/10.1007/s11123-012-0303-1.

Liao, H., Holmes, M., Jones, T. W., & Llewellyn D. (2007). Productivity growth of East Asia economies' manufacturing: A decomposition analysis. *Journal of Development Studies, 43*(4), 649-674. https://doi.org/10.1080/00220380701259723.

Mahamat, H. H. (2011). TFP growth, technological progress and efficiencies change: Empirical evidence from Canadian manufacturing industries. *International Journal of Productivity and Performance Management, 60*(4), 390-399. https://doi.org/10.1108/17410401111123535.

Minh, N. K., & Long, G. T. (2008). Factor productivity and efficiency of the Vietnamese economy in transition. *Asia-Pacific Development Journal, 15*(1), 93-117.

Minh, N. K., Minh, T. W., & Long, G. T. (2010, January 19-21). *A decomposition of total factor productivity growth in Vietnamese manufacturing industries: A stochastic frontier approach* [Paper presentation]. Proceedings of the DEA Symposium, Taiwan.

Minh, N. K., van Khanh, P., Minh, N. T., & phuong Anh, N. T. (2012). Productivity growth, technological progress, and efficiency change in Vietnamese manufacturing industries: A stochastic frontier approach. *Open Journal of Statistics, 2*, 224-235. http://dx.doi.org/10.4236/ojs.2012.22028.

Nishimizu, M., & Page, J. M. (1982). Total factor productivity growth, technological progress and technical efficiency change: Dimensions of productivity change in Yugoslavia, 1965-1978. *The Economic Journal, 92*(368), 920-936.

Shackleton, R. (2013). *Total factor productivity growth in historical perspective* (Working Paper No. 2013–01). Congressional Budget Office, Washington, DC.

Sickles, R., & Zelenyuk, V. (2019). *Measurement of productivity and efficiency: Theory and practice.* Cambridge, England: Cambridge University Press.

Tunisian Institute of Competitiveness and Quantitative Studies (TICQS). (2012). *Rapport Annuel sur la Compétitivité 2011*. Institut Tunisien de la Compétitivité et de l'Economie Quantitative, Tunis.

Tunisian Institute of Competitiveness and Quantitative Studies (TICQS). (2014). *Growth and productivity in Tunisia: State of play 1983-2010* (Secrétariat d'Etat du Développement et de la Coopération Internationale, TICQS/N°3/2014). République Tunisienne, Ministère de l'Economie et des Finances.

World Bank. (2014). *The Unfinished Revolution Bringing Opportunity, Good Jobs And Greater Wealth To All Tunisians* (Report No. 86179-TN). Tunisie: Development Policy Review.

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