11- Impacts of Public, Private, and R&D Investments on Total Factor Productivity Growth in Tunisian Agriculture

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Abstract

The paper analyzes the patterns of productivity and economic growth in Tunisian agriculture during the period 1981–2007. A regression approach is used to test the hypotheses that government-funded research, development and extension (RD&E), private and investment, terms of trade, and share of irrigated area are significant determinants of total factor productivity (TFP) in the agricultural sector.

Results indicate that agricultural output experienced moderate annual growth between 1981 and 2007. Over the whole period, land and capital were found to be the most important contributors to productivity, and labour and livestock the least significant. TFP contribution to agricultural output was important in the 1980s, less important in the 1990s, and became significant again between 2001 and 2007. The findings show that TFP growth was the result of investments in the agricultural sector, with the use of intensive irrigated production systems and the adoption of new production technologies.

We found significant negative cross-price elasticities between labour and capital suggesting that agricultural policies in the form of subsidies for agricultural machinery could be introduced without negatively affecting the agricultural labour force. Finally, Tunisian government should strengthen its domestic agricultural research system through a variety of policy tools that include joint public-private partnerships.

Keywords: Public & Private Investment; Agriculture; Tunisia; *Translog* Production Function; TFP

JEL: C8, O13, O14.

Impacts des Investissements Publics, Privés et en Recherche - Développement sur la Croissance de la Productivité Globale des Facteurs dans l'Agriculture Tunisienne

Résumé

Le papier analyse les tendances de la productivité et la croissance économique dans l'agriculture tunisienne au cours de la période 1981-2007. Une approche de régression est utilisée pour tester les hypothèses que le financement du gouvernement en recherche et développement et en vulgarisation (RD&E), les investissements privés, les termes de l'échange et la part de la superficie irriguée sont des déterminants clés de la productivité globale des facteurs (PGF) dans le secteur agricole en Tunisie.

Les résultats indiquent que la production agricole a connu une croissance annuelle modérée entre 1981 et 2007. Au cours de cette période, la terre et le capital ont été jugés les contributeurs les plus importants à la productivité. Au contraire, la main-d'œuvre et l'élevage ont étés moins importants. La contribution de la PGF à la production agricole a été importante dans les années 1980, moins importante dans les années 1990, et est devenue significative, de nouveau, entre 2001 et 2007. Les résultats montrent aussi que la croissance de la PGF a été le résultat d'investissements dans le secteur agricole, avec l'utilisation des systèmes irrigués intensifs et l'adoption de nouvelles technologies de production.

Ont été mises en évidence des élasticités-prix croisées entre travail et capital négatives et significatives. Ceci suggère que les politiques agricoles sous la forme de subventions pour les machines agricoles pourraient être introduites sans affecter négativement la main-d'œuvre agricole. Enfin, le gouvernement Tunisien devrait renforcer son système national de recherche agricole à travers une variété d'outils politiques visant, entre outres, à stimuler et à renforcer les partenariats public-privé.

Mots clés: Investissement Privé & Publique; Agriculture; Tunisie; Fonction de production *Translog*; PGF.

Introduction

Agriculture assumes significant social and economic importance in the Tunisian economy. The main contribution of the agricultural sector is not in terms of GDP, currently around 8 percent (USDS, 2011), but as a source of employment engaging approximately 700,000 people (20.5 percent of the working population) on a full-time basis (FAOSTAT, 2011; WFP, 2011). Particularly important are the number of jobs the agricultural sector generates for the most vulnerable: women, children, and the elderly. The National Institute of Statistics of Tunisia (INS, 2008) estimates that in 2005 (latest figures available), agriculture constituted 38 percent of total female employment, and in rural areas, - was the sole employer of women.

Given the importance of the agricultural sector, successive governments since the 1950s have sought strategies to increase production and productivity levels. After Tunisia obtained full independence from France in 1956, the newly independent government implemented a system of collective production which forced farmers to cultivate land through cooperatives. Under this system, the government was involved in all areas related to the production, transformation, and marketing of agricultural inputs and commodities. It also introduced a massive program of agricultural subsidies in the 1960s.

Subsidies significantly lowered the costs of agricultural inputs (over 50 percent in some cases) and were directly administered by the government which marketed subsidized inputs (fertilizers, seeds, irrigation systems, and chemical products) through parastatals (Thabet, Boughzala and Ben Ammar, 2002). Output prices were also subject to government intervention. In the 1960s, the government fixed agricultural prices (e.g. cereals, oils, milk, sugar, and meats) in order to lower the costs of sensitive commodities and guarantee food security for all segments of the Tunisian society. During the same period, an import substitution policy was also introduced (Nabli, 1980) which basically meant that domestic industry and agricultural sectors were protected with increased import tariffs. Most imports (e.g. wheat, milk, vegetable oil and sugar) and exports (e.g. olive oil, wine and dates) were channelled through state specialized agencies.

Some researchers (Thabet, Boughzala and Ben Ammar, 2002; Dhehibi and Lachaal, 2006) claim that these policies were not successful and cite various reasons: input subsidization schemes provided few incentives for resource conservation; price support programs distorted the domestic market allocation of resources; and heavy border protection made food more expensive for consumers. Thus, such policies were increasingly recognized as inefficient ways to achieve higher levels of production and productivity, and consequently, food security (Dhehibi and Lachaal, 2006). In addition, food subsidies seriously compromised government budgets, forcing the government to constantly demand more taxes and other sources of income to support an ever-growing subsidy bill that was inflated due to increased international prices. Moreover, Thabet, Boughzala and Ben Ammar (2002) found that approximately 80 percent of food subsidies went to urban areas, despite the fact that more than 40 percent of the Tunisian population lived in rural areas. This suggests that food subsidies were inefficiently administrated and unevenly distributed between rural and urban consumers.

In the 1980s, the Tunisian economy suffered serious structural imbalances due to slow economic growth, inflation, unemployment, and balance of payment deficits. In 1986, the government responded with the Structural Adjustment Program (SAP), recommended by the IMF and the World Bank, which coupled with Tunisia’s Agricultural Sector Adjustment Program (ASAP), represented the most important economic milestone in the past 25 years, and a new policy paradigm for the domestic economy. The ASAP aimed to: (i) remove the major sources of price distortions that adversely affected efficiency and productivity; (ii) transfer marketing functions that were under state control to the private sector; and (iii) improve public and private investment and management, including efforts to increase privatization.

These far-reaching reforms in the late 1980s, and throughout the 1990s, involved a gradual disengagement from price fixing, the removal of input subsidies, and the expansion of private investments. Tunisian society expected these reforms to pay-off in terms of higher productivity and enhanced food security. However, food production has never been able to meet domestic needs. Tunisia is currently a food-deficit country for key staples such as cereals, vegetable oil and sugar - although it has almost achieved self-sufficiency in dairy products, meat, and various vegetables and fruits (WFP, 2011).

Currently, markets for the majority of agricultural products are governed by free market forces. However, some price control policies remain in place such as prices for cereals, olive oil, and meats. These products can only be marketed through specific channels such as the *Office des Céréales* for grains and the *Office National de l'Huile* for olive oil. Farmers, on the one hand, benefit from price stabilization since they can sell products with guaranteed fixed prices and no limitations on quantity. On the other hand, they are unable to take advantage of increased international prices which would increase their profits. Obviously, the government has to keep storage houses at public cost.

The so-called 'Arab Spring' which started in Tunisia (January 2011) was the result of numerous social, economic and political issues. The street protests and social unrest were a response to many different grievances: poverty, lack of food security, rural and urban unemployment, government corruption, and human rights violations. In addition, the 'Arab Spring' reaffirmed the importance of the agricultural sector - not only for food security - but also for social, psychological, and political stability (Breisinger, Ecker and Al-Riffai, 2011).

The objective of this paper is to evaluate the productivity of the Tunisian agricultural sector. The only previous study on agricultural productivity in Tunisia (Dhehibi and Lachaal, 2006) assessed productivity based on capital, intermediate consumption, and labour explanatory variables, using data up to the year 2000. In order to achieve a more comprehensive understanding, this research also includes land and livestock productivity, and uses the latest available data: official Tunisian statistics from 2007.

In setting out this objective, we understand that the most important challenge facing Tunisia's agricultural sector is to meet increasing domestic demand without degrading the country's natural resource base. To meet this objective, we first investigated productivity growth during the period 1981–2007. The analysis was undertaken using a *translog* production function which provides a convenient framework for analyzing productive behaviour. We then used a regression approach to empirically test whether government-funded RD&E, private investment, public investment, terms of trade, or share of irrigated area in total cultivated land were significant determinants of TFP.

The remaining sections of the paper are structured as follows. Section 2 describes the theoretical foundation, the specification of the econometric model, and identifies possible determinants of TFP growth. Data issues and estimated procedures are outlined in section 3. Section 4 deals with the presentation and discussion of our empirical results. Finally, section 5 presents the conclusion and policy implications drawn from this study.

Theoretical background

Productivity growth is often cited as one of the major factors contributing to the sustained economic growth of a nation (Huffman, 1993). Firstly, agricultural productivity measurement is used to assess effectiveness in the use of natural resources. In Tunisia, land and water resources are limited, and it is therefore extremely important to make efficient use of these resources. Secondly, assessing agricultural productivity helps to understand the competitiveness of the agriculture sector, contributing to the identification of strategic policy actions to improve domestic food security (Hayami and Ruttan, 1985; Ball, 1985). Thirdly, productivity analysis is used to account for different sources of growth related to various changes in the production process, including technical efficiency and technological change (Fan, 1991; Capalbo, 1988).

The literature proposes two main formal approaches to measure agricultural productivity: non-parametric and parametric. Non-parametric approaches involve Data Envelopment Analysis (DEA), while parametric approaches comprise the index number and econometric methods[2]. Although parametrical procedures are

[2] For a detailed review of the literature on methods related to productivity growth measurement and explanations, see Lachaal (1998).

based on central tendencies, non-parametric approaches or DEA is an external process. The DEA measures the relative efficiency with respect to the entire set being evaluated, and is thus more suitable for comparing agricultural productivity among countries. More generally, the DEA is a methodology directed to frontiers rather than central tendencies (Emrouznejad and Thanassoulis, 2010). The Malmquist index has been most commonly used by non-parametric methods (Telleria and Aw-Hassan, 2011).

The parametric approach has widely used the Laspeyres Index to measure agricultural productivity through value added per unit of input. This index confirms whether an economy in the current period can afford to produce the same quantity as it consumed in the previous period. However, the Theil-Tornqvist Index is preferred to the Laspeyres Index because it not only uses prices from both the base and the comparison period but also rejects the unrealistic assumption that all inputs are perfect substitutes in production (Wiebe and Gollehon, 2006). Nevertheless, the Theil-Tornqvist Index does not satisfy transitivity conditions, making it inapplicable for cross-country comparisons (PrasadaRao and Selvanathan, 1990).

The econometric approach to the measurement of agricultural productivity is based on an econometric estimation of the production function. This estimation proposes a functional form of the production function to characterize the underlying technology, using the resulting system of equations to estimate the unknown parameters. The major weakness of this approach is the assumption of an explicit functional form for the technology which could make it difficult to identify the sources of inefficiency accurately (Berndt and Christensen, 1973). However, a very important advantage of this method is that it allows for statistical inference and estimations of TFP indicators. Given that the primary objective of this study is the assessment of productivity in the Tunisian agricultural sector, the parametric criterion, particularly the econometric approach, is the model of choice.

Econometric estimation for measuring agricultural productivity is not a new approach; there have been many publications applying econometric formulations to estimate agricultural productivity and compare technology and efficiency indicators. However, a review of the literature on agricultural productivity in Tunisia reveals -only two such studies: one by Dhehibi and Lachaal, (2006), and another by Telleria and Aw-Hassan (2011). The former analyses patterns of productivity and economic growth in Tunisian agriculture during the period 1961–2000, and the latter provides a cross-country comparison of agricultural productivity across twelve West Asian and North African countries (including Tunisia). Neither estimates an aggregate production model for Tunisian agriculture that simultaneously identifies substitution elasticities, input demand elasticities, the rate of productivity growth, or the impact of agricultural RD&E investments. By furthering our understanding of the factors driving agricultural productivity in Tunisia, as well as their policy implications, this paper will help to fill this gap.

Methodology

Following Ruttan (2002), this research on productivity measurement was implemented in three stages. In the first stage, we aimed at obtaining own and cross-price elasticities of production factors. To this end, we used the transcendental logarithmic (*translog*) function which can be considered a second-order Taylor series approximation for any arbitrary production function (Christensen, Jorgenson and Lau, 1973). The *translog* was used to obtain TFP growth estimates as well as to analyze factor input demands, substitution between production factors, and TFP growth rates. To avoid strong restrictions on the technology, the six-factor *translog* production function was used with the following specification:

$$Y = f(X, K, L, La, Li, T)$$

$$\begin{aligned} \mathrm{Ln}Y = {} & \alpha_0 + \alpha_X \mathrm{Ln}\,X + \alpha_K \mathrm{Ln}\,K + \alpha_L \mathrm{Ln}\,L + \alpha_{La} \mathrm{Ln}\,La + \alpha_{Li} \mathrm{Ln}\,Li + \alpha_T T \\ & + \tfrac{1}{2}\beta_{XX} \mathrm{Ln}\,X^2 + \beta_{XK} \mathrm{Ln}\,X\,\mathrm{Ln}\,K + \beta_{XL} \mathrm{Ln}\,X\,\mathrm{Ln}\,L + \beta_{XLa} \mathrm{Ln}\,X\,\mathrm{Ln}\,La + \beta_{XLi} \mathrm{Ln}\,X\,\mathrm{Ln}\,Li + \beta_{XT} \mathrm{Ln}\,X\,T \\ & + \tfrac{1}{2}\beta_{KK} \mathrm{Ln}\,K^2 + \beta_{KL} \mathrm{Ln}\,K\,\mathrm{Ln}\,L + \beta_{KLa} \mathrm{Ln}\,K\,\mathrm{Ln}\,La + \beta_{KLi} \mathrm{Ln}\,K\,\mathrm{Ln}\,Li + \beta_{KT} \mathrm{Ln}\,K\,T \\ & + \tfrac{1}{2}\beta_{LaLa} \mathrm{Ln}\,La^2 + \beta_{LaLi} \mathrm{Ln}\,La\,\mathrm{Ln}\,Li + \beta_{LaT} \mathrm{Ln}\,La\,T \\ & + \tfrac{1}{2}\beta_{LiLi} \mathrm{Ln}\,Li^2 + \beta_{LiT} \mathrm{Ln}\,Li\,T \\ & + \tfrac{1}{2}\beta_{TT} T^2 \end{aligned} \quad (1)$$

Where *Y* is the value of agricultural output, other values are given by intermediate inputs (*X*), capital (*K*), labour (*L*), land (*La*), and livestock (*Li*). *T* represents the time trend proxy and *Ln* is the natural logarithm. The *αs* and *βs* are parameters to be estimated. The function is symmetric so that $\beta_{ij}= \beta_{ji}$. We assume that the production function is characterized by constant returns to scale. Under this assumption, the share of each input in the value of output is equal to the elasticity of output with respect to that input, and the value shares sum up to unity. Given the functional form defined in equation (1), and applying the Sheppard's Lemma, the value shares for each input are estimated as follows:

$$\begin{aligned}
S_X &= \alpha_X + \beta_{XX} Ln\ X + \beta_{XK} Ln\ K + \beta_{XL} Ln\ L + \beta_{XLa} Ln\ La + \beta_{XLi} Ln\ Li + \beta_{XT} T \\
S_K &= \alpha_K + \beta_{XK} Ln\ X + \beta_{KK} Ln\ K + \beta_{KL} Ln\ L + \beta_{XLa} Ln\ La + \beta_{KLi} Ln\ Li + \beta_{KT} T \\
S_L &= \alpha_L + \beta_{XL} Ln\ X + \beta_{KL} Ln\ K + \beta_{LL} Ln\ L + \beta_{LLa} Ln\ La + \beta_{LLi} Ln\ Li + \beta_{LT} T \\
S_{La} &= \alpha_{La} + \beta_{XLa} Ln\ X + \beta_{KLa} Ln\ K + \beta_{LLa} Ln\ L + \beta_{LaLa} Ln\ La + \beta_{LaLi} Ln\ Li + \beta_{LaT} T \\
S_{Li} &= \alpha_{Li} + \beta_{XLi} Ln\ X + \beta_{KLi} Ln\ K + \beta_{LLi} Ln\ L + \beta_{LaLi} Ln\ La + \beta_{LiLi} Ln\ Li + \beta_{LiT} T
\end{aligned} \qquad (2)$$

Equation (1), and the set of equations contained in (2), form a simultaneous equation whose parameters, to be estimated, must satisfy production technology characterized by constant returns to scale, as follows:

$$\begin{aligned}
\alpha_X + \alpha_K + \alpha_L + \alpha_{La} + \alpha_{Li} + \alpha_T &= 1 \\
\beta_{XX} + \beta_{XK} + \beta_{XL} + \beta_{XLa} + \beta_{XLi} &= 0 \\
\beta_{XK} + \beta_{KK} + \beta_{KL} + \beta_{KLa} + \beta_{KLi} &= 0 \\
\beta_{XL} + \beta_{KL} + \beta_{LL} + \beta_{LLa} + \beta_{LLi} &= 0 \\
\beta_{XLa} + \beta_{KLa} + \beta_{LLa} + \beta_{LaLa} + \beta_{LaLi} &= 0 \\
\beta_{XLi} + \beta_{KLi} + \beta_{LLi} + \beta_{LaLa} + \beta_{LiLi} &= 0 \\
\beta_{XT} + \beta_{KT} + \beta_{LT} + \beta_{LaT} + \beta_{LiT} &= 0
\end{aligned} \qquad (3)$$

The main reason for choosing Christensen, Jorgenson and Lau's (1973) *translog* function was that it allows measurement of TPF growth and examination of its differentials across time with a single stage estimation procedure. With the assumption of identically distributed TFP effects in the transcendental function, which is necessary in the *Maximum Likelihood* (ML) estimation, the commonly applied two-stage estimation procedure has been recognized as inconsistent (Christensen, Jorgenson and Lau, 1973). However, the two-stage estimation procedure can be used for identifying the determinants affecting TFP growth within a given timeframe since TFP is calculated from the parameters estimated in the set of equations (2).

In the second stage, we estimated productivity growth for Tunisian agriculture. This estimation was based on the concept of the *Divisia index* which allows for multifactor productivity calculations, using quantity indexes that incorporate changes in shares. The resulting index number series are unitless like other index numbers. However, the *Divisia index* has an operational problem since it only works with exact data generated continuously. To make this index operational, we used a discrete approximation given by the *Törnqvist* index. Mathematically, the *Törnqvist index* is calculated (in log form) between any two consecutive time periods, *t* and *t+1*, as follows:

$$TFP_{t,t+1} = Ln\ Y_{t+1} – Ln\ Y_t - \sum_i ½\ [S_{i,t+1} + S_{i,t}][Ln\ X_{i,t+1} – Ln\ X_{i,t}] \qquad (4)$$

Where $LnY_{t+1}$is the natural logarithm (*log*) of agricultural output in periods *t* and *t+1*, S_i denotes the respective input value shares in periods *t* and*t+1*' and $Ln\ X_{i,t+1}$is the natural log of input *i* at periods *t* and *t+1*. The *Törnqvist index* requires that the shares result in perfect aggregation. This is ensured by the assumption of constant returns to scale.

In the third stage, we conducted an econometric estimation of the relationship between TFP growth and different factors, including agricultural research and development investments. In a stylized form, we used the following regression model (expected signs in parentheses):

$$TFP = f\ (R, PR, PI, TT, IA) \qquad (5)$$

Where:

TFP = Total Factor Productivity in the agricultural sector;

R (+) = Share (in percentage) of public investment in RD&E with respect to Total Government Investment (i.e. government investment in agricultural RD&E);

PR (+) = Share (in percentage) of private investment in agricultural sector with respect to Total Government Investment (e.g. private investment on working capital, assets, private infrastructure and equities);

PI (+) = Share (in percentage) of public investment with respect to Total Government Investment (e.g. water technologies);

TT (+) = Export – import value ratio (in percentage);

IA (+) = Share (in percentage) of irrigated land with respect to total cultivated land.

The log-linear form of equation (5) is estimated because this specification presents the advantage that estimated coefficients can be interpreted directly as elasticities. In addition, as pointed out in the pioneering work by Jud and Joseph (1974), it contains a weak residual variance relative to other functional forms for the same data set and adjusts the data better than the linear specification for both forecasted parameter signs and statistical significance.

The standard OLS method, if applied to non-stationary data series, can produce spurious regression. That is, the OLS regression can give high R^2, low Durbin-Watson (DW) statistics, and significant t-values of the estimated coefficients, suggesting a significant relationship between dependent and explanatory variables, when in fact they are completely unrelated. Conventionally, the factors explaining TFP have been studied by expressing variables in logarithmic form. This is similar to the first differencing of variables in time series analysis. Provided the original series are integrated of order 1, as is normally the case, expressing the variables in logarithmic terms ensures a stationary data series and means that the OLS method can safely and directly be used (Hendry, 1995).

Data sources and estimation procedure

To implement the above-specified model, we used annual agricultural data covering the period from 1981 to 2007. That is, annual data on the value of agricultural outputs, intermediate inputs, capital, labour, land, livestock (proxied by investment in livestock sector), private agricultural investment, public agricultural investment, terms of trade and total government investments in agricultural RD&E were used. All these variables were measured in Tunisian Dinars valuated at 1990 constant prices which enabled us to estimate the parameters. This information was taken from the Yearly Statistics Data of the Ministry of Agriculture, Irrigation Resources and Fisheries of the Tunisian Government (MAIRF). Labour and intermediate input data were collected from the Tunisian *Institut National de la Statistique* (TINS), and capital stock data was collected from the *Institut d'Economie Quantitative* (IEQ). Although information on the price of land is unavailable in Tunisia, this variable is necessary to estimate TFP. In order to estimate the value of land, we relied on the value-added approach to estimate GDP. That is, estimating the contribution of land value added by deducting from agricultural GDP the value added of labour, capital, and intermediate inputs.

The system of equations, as outlined above, consists of the agricultural output equation (1) and five value-share equations (2) that are set up to be solved as a simultaneous equations system. The set of seemingly unrelated equations (1) and (2) is solved using Zellner's iterative seemingly unrelated regression (ITSUR) procedure. This allows us to estimate several regression equations (i.e. LnY in equation 1 and S_X, S_K, S_L, S_{La}, and S_{LI} in Equation (2)), each having their own dependent variable and exogenous explanatory variables. Note that the value shares in equation (2) have to add up to one, and hence only n−1 of the value shares are linearly independent. This implies that the covariance matrix is singular and non-diagonal (Berndt, 1991). To solve the singularity problem, the livestock equation (S_{Li}) was arbitrarily dropped from the estimation. The parameter estimates and their variances can be derived from the parameter estimates of the remaining equations based on the adding-up and symmetry restrictions.

As part of the estimation procedure, we first tested for auto-correlation. The resulting DW statistics from preliminary estimations suggested that auto-correlation was not a problem. Furthermore, an important part of the estimation was to calculate price elasticities. These provide a measure of the effects of a percentage change in the price of input *i* on the demand for input *j*. The price elasticities are defined as $\varepsilon_{ij} = S_j\,\sigma_{ij}$, where S_j is the estimated value-share of the j^{th} input, and σ_{ij} is the Allen partial elasticity of substitution. Allen elasticity is defined as follows:

$$\sigma_{ij} = \sum^{n}_{h=1} \sum_{h=1}^{n} F_h X_h \,|\, \bar{F}_{ij} | \,/\, X_i X_j \,|\, \bar{F} \,| \qquad (6)$$

Where $|\ \bar{F}\ |$is the determinant of the bordered Hessian, and$|\ \bar{F}_{ij}|$ is the cofactor of F_{ij} in *F*. The price elasticities are crucial when analysing the effects of price changes on input demand, especially if public commodity pricing policies are involved.

Results and Discussion

Parameter estimates of the aggregated production function for Tunisian agriculture are presented in Table 1. Most of the coefficient estimates are significant at five percent level. The results show that changes in agricultural productivity in Tunisia during the period 1981–2007 have mainly been driven by changes in capital (β_{KT}= 0.0047, *p*= 0.066). Labour (β_{LT}= 0.0019, *p*= 0.335) and intermediate inputs (β_{XT}= 0.0009, *p*= 0.575), although having no significant p-values, have the expected sign towards the improvement in agricultural productivity. Changes in livestock (β_{LiT} = -0.056, *p*= 0.014) over time indicate that investments in this sector have not been determinant to improve agricultural productivity growth. These findings identify the different factors that potentially explain agricultural productivity growth in Tunisia over the past three decades, with capital emerging as the main driving force.

Table 1.Parameter estimates of the aggregate production function for Tunisian agriculture, 1981–2007.

#	Parameters	Estimate	Standard error	P-value	#	Parameters	Estimate	Standard error	P-value
1	α_0	0.177	0.092	0.056	15	β_{XL}	-0.025	0.029	0.382
2	α_X	0.189	0.026	0.000	16	β_{XLa}	-0.036	0.013	0.005
3	α_K	0.124	0.039	0.002	17	β_{Xli}	-0.030	0.032	0.352
4	α_L	0.166	0.031	0.000	18	β_{XT}	0.0009	0.0016	0.575
5	α_{La}	0.213	0.015	0.000	19	β_{KL}	-0.075	0.025	0.003
6	α_{Li}	0.158	0.117	0.177	20	β_{KLa}	-0.029	0.011	0.007
7	α_T	-0.029	0.011	0.008	21	β_{KLi}	0.044	0.041	0.278
8	β_{XX}	0.118	0.026	0.000	22	β_{KT}	0.0047	0.0026	0.066
9	β_{KK}	0.085	0.027	0.002	23	β_{LLa}	-0.02	0.020	0.309
10	β_{LL}	0.086	0.046	0.065	24	β_{LLi}	0.036	0.043	0.402
11	β_{LaLa}	0.17	0.028	0.000	25	β_{LT}	0.0019	0.002	0.335
12	β_{LiLi}	0.032	0.072	0.653	26	β_{LaLi}	-0.082	0.028	0.004
13	β_{TT}	0.0021	0.0006	0.001	27	β_{LaT}	-0.0008	0.001	0.394
14	β_{XK}	-0.025	0.019	0.191	28	β_{LiT}	-0.056	0.023	0.014

Source: Own elaboration, with computed values of the Christensen transcendental logarithmic function based on figures from the Yearly Statistics Data - Ministry of Agricultural, Irrigation Resources and Fisheries of the Tunisian Government, the Tunisian *Institut National de la Statistique*, the *Institutd'Economie Quantitative*, and the FAO-AGROSTAT system (online database).

One of the key parameters in this study was the estimation of price elasticities. Table 2presents the mean values of own-price elasticities for the total period. Estimates for price elasticities[3] of intermediates (ε_{XX}= −0.184, *p*= 0.075), capital (ε_{KK}= −0.367, *p*= 0.009), labour (ε_{LL}= −0.366, *p*= 0.122), and livestock (ε_{LiLi}= -0.636, *p*= 0.067) indicate that production factor prices have caused a small production factor demand reaction within the Tunisian agricultural sector.

In the case of intermediate inputs, important implications emerge from these findings. Firstly, the input subsidies that have been progressively discontinued since the 1986 onwards have not significantly affected

[3] These estimates correspond reasonably closely to those provided by Dhehibi and Lachaal (2006).

the demand for agricultural inputs. Therefore, the policies for removing input subsidies under the ASAP[4] have not seriously affected the capacity of the Tunisian agricultural sector to continue using agricultural inputs. Apart from removing input subsidies (intermediates in Table 2), the ASAP moved the economy towards liberalization and integration into the global economy. Measures undertaken included input price liberalization and reductions in both tariff and non-tariff trade barriers. These policies further exposed the domestic economy to changes in international market prices. With the removal of input subsidies, and increased demand for agricultural inputs, the price of inputs increased domestically. However, due to inelasticity in intermediates ($\varepsilon_{XX}= -0.184$), farmers faced a larger bill for expenditure on agricultural inputs.

Regarding capital, the finding of low inelasticity supports the conclusion that the main driver of agricultural productivity change in Tunisia has been capital production factors. That is, even when the price of capital factors increased, the use of this factor decreased at a rate that was not proportional to the augmentation. Consequently, the demand for capital continued over time, prompting to agricultural productivity growth in Tunisia.

For labour, demands were also estimated to be inelastic. This reflects the fact that the Tunisian labour market is characterized by youth migration from rural to urban areas, many leaving agricultural farms (most of them family run) in the hands of women and elderly workers. Thus, even when wages increased in the agricultural labour market, particularly during the harvesting season when labour is scarce and a young workforce is needed to undertake physically-demanding agricultural work, demand did not decrease significantly.

Table 2. Mean values of own- price elasticities of the aggregate production function for Tunisian agriculture, 1981–2007.

Parameters	Mean	Standard error	T-statistics	P-value
ε_{XX} (intermediates)	-0.184	0.141	-1.77	0.075
ε_{KK} (capital)	-0.367	0.140	-2.61	0.009
ε_{LL} (labour)	-0.366	0.236	-1.54	0.122
ε_{LaLa} (land)	0.023	0.137	0.172	0.863
ε_{LiLi} (livestock)	-0.636	0.347	-1.829	0.067

Source: Author's calculation, based on coefficient estimates of the *translog* production function.

In the case of land, the estimated parameter ($\varepsilon_{LaLa}= 0.023$, $p= 0.863$) was not significant. However, important investments to expand irrigated areas have been taking place in Tunisia since the early 1990s. Rainfed lands were converted into irrigated, which increased not only the price of land, but also its demand.

With respect to the livestock sector, the government has been encouraging animal production to increase national self-sufficiency in meat and milk products in the past two decades. Livestock production has increased steadily and become an important contributor to agricultural GDP (40 percent). This favourable trend can be explained by increasing prices for meats (beef and sheep), which given the low demand inelasticity for livestock, have meant increased benefits for livestock producers. Furthermore, the extension of irrigated lands produced larger amounts of fodder which encouraged livestock expansion. From the early 1990s onwards, the private sector found it profitable to import pregnant heifers, fatten and slaughter, and finally supply the meat to a mostly domestic market.

[4] Since the late 1980s onwards, the agricultural sector has been driven by the ASAP. Funded by the International Monetary Fund and the World Bank, and implemented by the Tunisian government; the Program has led to the gradual discontinuation of input subsidies. The ASAP discontinued public agricultural investments, and advocated for the increased involvement of the private sector in agricultural capital, emphasizing the cultivation of export crops.

All estimated cross-price elasticities were less than one in absolute value (Table 3). A negative value for the partial elasticity of substitution indicates that the pairs of inputs are complementary, while a positive value indicates that they are substitutes. In fifteen out of twenty cases, pairs of production factors exhibit substitutability, with the largest positive cross-price elasticities between livestock and capital (ε_{KLi}= 0.413, *p*= 0.038) and livestock and labour (ε_{LLii}= 0.37, *p*= 0.074). This suggests that a percentage change in the price of livestock inputs has a positive effect on demand for capital and labour, and only a modest positive effect on the demand for intermediate inputs.

Table 3. Mean values of cross-price elasticities of the aggregate production function for Tunisian agriculture, 1981–2007.

Parameters		Mean	Standard error	T-statistics	P-value
ε_{XK}	(intermediates / capital)	0.064	0.101	0.63	0.524
ε_{XL}	(intermediates / labour)	0.060	0.156	0.38	0.700
ε_{XLa}	(intermediates / land)	0.014	0.069	0.198	0.843
ε_{Xli}	(intermediates / livestock)	0.045	0.174	0.259	0.795
ε_{KX}	(capital / intermediates)	0.061	0.096	0.636	0.524
ε_{LX}	(labour / intermediates)	0.057	0.149	0.385	0.700
ε_{LaX}	(land / intermediates)	0.012	0.062	0.198	0.843
ε_{LiX}	(livestock / intermediates)	0.041	0.158	0.259	0.795
ε_{KL}	(capital / labour)	-0.185	0.130	-1.49	0.136
ε_{KLa}	(capital / land)	0.057	0.056	1.02	0.305
ε_{KLi}	(capital / livestock)	0.433	0.208	2.079	0.038
ε_{LK}	(labour / capital)	-0.49	0.267	-1.85	0.064
ε_{LaK}	(land / capital)	-0.19	1.26	-0.15	0.879
ε_{LiK}	(livestock / capital)	0.413	0.198	2.07	0.038
ε_{LLa}	(labour / land)	0.103	0.103	1.00	0.316
ε_{LLi}	(labour / livestock)	0.39	0.21	1.78	0.074
ε_{LaL}	(land / labour)	0.603	0.72	0.833	0.404
ε_{LiL}	(livestock / labour)	0.37	0.208	1.78	0.074
ε_{LaLi}	(land / livestock)	-0.18	0.137	-1.47	0.071
ε_{LiLa}	(livestock / land)	-0.18	0.138	-1.46	0.072

Source: Author's calculation, based on coefficient estimates of the *translog* production function.

An interesting finding was a negative cross-price elasticity between labour and capital (and *vice-versa*) (ε_{LK}= -0.49, *p*= 0.064). This indicates complementarity in the use of these inputs when their relative price changes. In the case of Tunisia, this is explained by the low wages and underemployment that have prevailed in the agricultural sector allowing for lowered price of agricultural capital goods ending up in increasing demand for labour. A useful policy implication is that measures oriented to capital-intensive use in the agricultural sector (such as subsidies for mechanization and equipment) can be introduced without negatively affecting the demand for labour used in agriculture.

This is an important finding and undermines the fear that small farm mechanization is a substitute for manual power. Several researchers (Rahman et al, 2011; Smith and Gascon, 1979) conclude that mechanization of agricultural production has displaced agricultural labour, particularly in countries like Tunisia where labour is abundant and farm operations are labour intensive. However, the experience of olive production in Tunisia demonstrates that mechanization allows for higher production and the intensification of land cultivation which actually increases the requirement and demand for labour. Thus, small farm mechanization does not necessarily displace labour. In fact, harvesting and post-harvesting labour can have an offsetting effect on the amount of labour displaced by mechanized land preparation.

In relation to the main drivers of agricultural output growth in Tunisia, Table 4presents the results for average annual growth rates of output, weighted growth rates of inputs, and TFP growth rates. Results indicate that mean output growth rates increased in all periods. In the first period (1981–1990), TFP growth (1.20 percent annual average) was clearly the dominant source of output growth in Tunisian agriculture, while labour input growth (0.003 percent) was less important. In 1991–2000, land and capital inputs were the most important contributors (0.41 and 0.26 percent annual average, respectively) to output growth, reflecting the impacts of large development projects such as *Projets de Développement Rural Intégrés I* and *II* (PDRI). These publically-funded projects, implemented as part of Tunisia's ASAP, promoted the widespread use of irrigated technologies and significantly expanded areas under irrigation.

In 2001–2007, productivity growth was the most important single contributor (1.82 percent annual average). By this period, the PDRI programs had finished and were replaced by large government-driven extension projects under the umbrella of the Ministry of Agriculture. Agricultural extension and irrigation projects increased efficiency in the use of agricultural inputs.

Table 4. Average annual growth rates of output and weighted growth rates of inputs and productivity growth for Tunisian agriculture (percent).

Period	Output growth	Weighted growth rate of inputs: Intermediate	Capital	Labour	Land	Livestock	TFP growth
1981–1990	1.38	0.04	0.017	0.003	0.05	0.019	1.20*
1991–2000	1.62	0.11	0.265	0.0029	0.41	0.065	0.76*
2001–2007	2.04	0.04	0.025	0.0068	0.17	0.033	1.82*
Mean	1.60	0.06	0.11	0.004	0.188	0.022	1.20

* The ANOVA analysis, used to test significance for difference in TFP growth between the three periods, indicate the mean real average TFP growth rate for the three periods are statistically different.
Source: Author's calculation, with computed values of the *Törnqvist index.*

The annual growth rate of intermediate inputs (such as fertilizers) during 2001–2007 was not significant (0.04 percent). This might be explained by increased international input prices and import restrictions which the Tunisian government applied to imported inputs due to lack of foreign exchange. Livestock growth increased at low rates between 1981–1990 (0.019 percent per year) and 1991–2000 (0.065 percent per year). However, between 2001 and 2007, livestock growth rates slowed down considerably (0.033 percent per year) due to increased feed prices in international markets and low productivity within the small ruminant sector (Elloumi *et al.*2008).

We conclude that in general TFP was growing from 1981 to 2007, at rates that fluctuated between 0.76 percent and 1.82 percent per year on average. In 1991–2000, the growth of TFP decelerated in comparison with the other two periods. A possible explanation for this deceleration is inefficiencies in the use of technology and know-how which were exacerbated by unfavourable drought throughout the 1990s. Supporting this finding, Latiri (2005) reports low productivity in the cereal sector in the 90s, one of the most important in Tunisian agriculture. Saï and Msallem (2005) also report low productivity in the olive sector in the 90s, particularly in the Northern part of the country, where although technical production conditions are the most favourable in Tunisia, but yet experienced poor performance.

To precisely measure the impact of investment in agricultural RD&E, irrigated land, private investment, public investment, and terms of trade on TFP, a regression model, as specified in equation 5 was used. Based on F-statistics, results indicate the overall significance of the model (Table 5). The share of irrigated land, private investments, and irrigation infrastructure were the most important drivers of TFP growth, implying that a one percent increase in these factors, with respect to national investment, would lead to increases in TFP growth of 0.11, 0.08, and 0.063 percent respectively[5].

[5] Since all variables are measured in logarithms, the regression coefficients are elasticities and the size of the coefficients indicate the magnitude of their relative influence upon TFP.

Table 5.TFP determinants in agricultural sector (1981–2007).

	Dependent variable $LnTFP_t$		
Parameters	Estimated coefficients	t-ratios	p-value
Constant	0.409	2.14	0.0445
LnR_t(investment in agricultural RD&E)	0.0055	0.121	0.9043
$LnIRR_t$ (irrigated land)	0.115	1.561	0.1340
$LnPR_t$ (private investment)	0.081	1.502	0.1534
$LnPI_t$ (public investment)	0.063	1.800	0.1228
$LnTT_t$ (terms of trade)	0.064	0.9239	0.3665
T	27		
F-statistic	1.1948 (p<0.347)		
Log likelihood	59.35		

Source: Author’s calculation based on coefficient estimates of the linear regression model.

The agricultural RD&E coefficient was positive but not significant (0.0055, p= 0.9043). This may be due to the low share of RD&E investments in agricultural GDP (which represent 0.5 percent, on average, for the 1981–2007 period). However, this positive relationship is consistent with empirical studies that find a direct correlation between investments on agricultural RD&E and TFP (Fuglie, 1999; Ruttan, 2002; and Thirtle, Lin and Piesse, 2003).

Private investment is statistically significant (p= 0.1534) while publically-funded RD&E was found to be positive but not significant. Both findings support the relatively new private public partnership (PPP) development paradigm (Moszoro and Gasiorowski, 2008; IFPRI, 2007; and Quiggin, 1996), which for the case of Tunisia would be a different and novel approach advocating for a joint research system to foster technical and efficiency improvements in the domestic agricultural sector. Investment in agricultural RD&E induces productivity growth, offering a potential solution to the challenge of maintaining a continuous increase in agricultural output in a manner that minimizes input use, protects the natural resource base, and enhances food security (CGIAR, 2009).

For Tunisia, Elloumi and Dhehibi (2010) also found evidence indicating a positive relationship between investments in the agricultural sector and TFP growth. Productivity-enhancing investments in developed countries have encouraged public-private research partnerships which have achieved worldwide improvements in agricultural technologies (Pardey, Alston and Piggot, 2006). The new Tunisian government should consider encouraging not only Tunisian public-private alliances but also partnerships with other Mediterranean and worldwide research institutions (CGIAR, among others).

Our estimated coefficient of public investment was significant (0.063, p= 0.1228). This may be due to the fact that in Tunisia public investment (e.g. government expenditure in roads, bridges, railway tracks, harbors and airports) has mostly benefited urban sectors, with few positive spillovers for agricultural development. Hermes and Lensink (2001) argue that public investment is not necessarily development-oriented. They classify public investment into development and non-development expenditures, which combined with private investments, can have mixed results for national economic growth. Non-development government expenditures affect private investment positively via demand channels but may also affect it negatively in terms of budget deficits, future taxes, and the absence of complementary effects on investments. However, when public investment favours rural and agricultural sectors, several studies, including Aschaver (1989), Greene and Villanueva (1991), Munnell (1992), Oshikaya (1994), Ghura and Goodwin (2000), and Mamatzakis (2001) suggest a positive relationship between public investment (or expenditures) and agricultural development.

The estimated coefficient of the terms of trade was positive, as expected, but not significant (0.064, p= 0.3665). This may be due to the deterioration of the terms of trade that Tunisia has experienced in the past 30 years. According to UNCTAD (2010) estimates, the value of the net barter terms of trade index (2000 =

100)[6] in Tunisia decreased from 123.60 in 1980 to 89.65 in 2007. This means depreciation in the terms of trade which compels the economy to decrease its final demand as the cost of imported goods increase, a development that does not favour TFP growth.

The coefficient estimate of irrigated land with respect to total agricultural land was significant (0.115, p= 0.1340), suggesting that government investment in irrigation schemes has been a positive determinant of TFP in Tunisian agriculture.

Conclusions and policies implications

In this paper we first analysed the performance of Tunisia's agricultural sector during the period 1981–2007, and then identified the impact of public and private investments, paying special attention to investment in agricultural RD&E. Results indicate that agricultural output experienced moderate annual growth between 1981 and 2007, at a rate of 1.6 percent per year. This figure was below the country's population growth, 1.96 percent (own calculation based on FAOSTAT) per year for the same period, prompting concerns about Tunisia's ability to feed its growing population. Our results suggest that intensification of production systems is needed to achieve the goal of food security. Of course international trade can supplement food gaps, though stakes can be high if world food prices sky up as they did in 2007–2008.

Over the whole period, land was the most important contributor to agricultural output growth, followed by capital. In particular, land growth was high in 1991–2000 but later decreased in 2001–2007. Mean growth rates of intermediate inputs and livestock subsequently decreased in 2001–2007. Labour was the least significant source of growth for agricultural output.

TFP fluctuated over the period of investigation: its contribution to agricultural output growth decreased from 1.2 percent in 1981–1990 to 0.76 percent in 1991–2000 but increased to 1.8 percent in 2001–2007. On average, the annual growth rate of TFP was smaller than agricultural output growth rates. Productivity growth has occurred because of investments in the agricultural sector, particularly in the last decade with the use of intensive production systems, water resource mobilization (i.e. irrigation), and the adoption of new production technologies. These findings have important policy implications for promoting further growth in Tunisian agriculture. Increased productivity is important for Tunisia's competitiveness as the country looks to take further advantage of existing bilateral and multilateral trade partnerships (e.g. World Trade Organization, Euro-Med Free Trade Area, and the Arab Maghreb Union).

The positive impact of public investment suggests that Tunisia should now invest more comprehensively in its own agricultural infrastructure, especially in efficient water management technologies. Furthermore, if the significance of public agricultural investment is fully recognized, and it is to be used effectively as a policy tool to improve agricultural output and consequently food security using fewer resources, then a greater policy commitment is needed to strength public-private partnership investments in the agricultural sector. The empirical findings indicate that private investment in the agricultural sector was one of the major determinants of TFP growth. The corresponding coefficient was statistically significant, suggesting that policymakers should encourage such investments in the agricultural sector through the implementation of well-targeted public-private partnerships that channel funding to infrastructural projects.

Agricultural policies such as subsidies to agricultural machinery or equipment can also be introduced without negatively affecting the rural labour force. This policy recommendation is supported by cross-price elasticities between capital and labour, indicating complementarity between these two inputs when used in agriculture. Thus, the adoption of farm mechanization will not displace agricultural labour since mechanization intensifies production (i.e. more output), offsetting possible effects on labour displacement. For example, the mechanization of olive production in Tunisia caused an increment in the requirement of agricultural labour.

[6] Net barter terms of trade index is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000.

Finally, this is the first study that has estimated the impact of agricultural RD&E on TFP in Tunisia. Even though we did not find the estimated coefficient to be significant, we did find a positive correlation. As indicated above, the reason for this maybe the limited financial resources allocated to RD&E, in comparison to total agricultural public investment. However, this positive correlation could indicate to the national government the need to -strengthen its domestic agricultural research system. For example, public RD&E -could be allocated to the improvement of research for farm systems that are not of interest to the private sector. By definition, the nature of public goods tends to generate uncertainty in obtaining profitable results, making the private sector generally reluctant to invest in overall farm system research programs. In addition, the level of government spending on public RD&E is insufficient to compensate the under-investment of the private sector. Instead, policymakers could play a more active role encouraging increased investments, not only in production systems, but also in RD&E through a variety of policy tools that induce joint public-private co-investments.

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