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IMPACT OF THE ADOPTION OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON FIRM EFFICIENCY IN THE TUNISIAN MANUFACTURING SECTOR

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Abstract

This paper aims at measuring the impact of information and communication technologies (ICT) use on the efficiency of the Tunisian manufacturing sector, at the firm level within a simple theoretical framework. We use a firm-level panel data for the manufacturing sector in Tunisia to investigate whether adoption of ICT influences efficiency in factors use. The analysis is conducted through the use of a parametric method to measure technical efficiency. We estimate a stochastic production frontier and the relationship aimed to explain technical efficiency differentials in a single stage as suggested by Battese and Coelli (1995). The results confirm the presence of positive returns to ICT capital. We find that the impact of ICT on efficiency is strong. Our results also suggest that it is important to carefully control for human capital related characteristics of employment when studying the effect of ICT. The evidence shows that achieving benefits from investment in ICT requires complementary investments and changes in human capital. This means that the combined use of ICT and human capital in a firm would enhance its efficiency beyond the direct effects of these factors taken alone.

ملخص

تهدف هذه الورقة إلى قياس مدى تأثير استخدام تكنولوجيا المعلومات والاتصالات على كفاءة قطاع التصنيع التونسي وذلك على مستوى ثابت ضمن إطار نظري بسيط. ونحن نستخدم هنا بيانات إحصائية على مستوى الشركات في قطاع التصنيع في تونس من أجل الوقوف على ما إذا كان هناك ثمة تأثيرات على الكفاءة والأداء في حال استخدام تكنولوجيا المعلومات والاتصالات. وقد تم إجراء التحليل من خلال استخدام طريقة إحصائية بارا مترية لقياس الكفاءة الفنية وقمنا بتقييم حد إنتاجي عشوائي والعلاقة التي من خلالها يمكن بيان التغيرات الحادثة في الكفاءة الفنية في مرحلةٍ بعينها كما اقترحاها كلٌ من باتيز وكويلي 1995. وقد أكدت النتائج أن ثمة مردود إيجابي في حال استخدام تكنولوجيا المعلومات والاتصالات، كما وجدنا أن تأثير تكنولوجيا المعلومات والاتصالات على الكفاءة كان قوياً. وتبين نتائجنا أنه من الأهمية بمكان أن يتم الالتفات إلى خصائص التوظيف المرتبطة برأس المال البشري عند مباشرة دراسة تأثير تكنولوجيا المعلومات والاتصالات. إن ثمة دليل على أنه من أجل تحقيق أرباح ومكاسب من الاستثمار في تكنولوجيا المعلومات والاتصالات فإن ذلك يستلزم استثمارات تكميلية وتغييرات في رأس المال البشري؛ ما يعني أن الاستخدام المشترك المتزامن لكلٍ من تكنولوجيا المعلومات والاتصالات والعنصر البشري في شركة ما سيؤدي بالضرورة إلى تعزيز كفاءة هذه الشركة بخلاف ما إذا ما استخدم كل عامل من هذين العاملين بشكلٍ منفصلٍ.

1. Introduction

The great expansion of information and communication technologies (ICT) that has taken place during the last decade has set the stage for a new age of opportunities and challenges in many economic regions. ICT provide speedy, inexpensive and convenient means of communication. The adoption of these technologies (internet, mobile telephony and broadband networks) in many developed countries was found to have a positive effect on the organization's performance. But not all countries are taking advantage of this kind of revolution in the same way and at the same pace. According to the World Bank (2006), "firms that use ICT grow faster, invest more, and are more productive and profitable than those that do not."

Many studies that cover the experience of developed countries conclude with a positive relationship between ICT use and superior performance (Baldwin and Sabourin, 2001). However, based on the findings of many other studies, Lefebvre (1996) conclude that the "IT–productivity connection remains elusive, with contradictory results from study to study." Some authors are still doubtful on the empirical relevance of ICT effects on productivity. In many countries — more often the developed — these effects have yet to materialize.

This paper aims at measuring the impact of ICT use on the efficiency of the Tunisian manufacturing sector at the firm level within a simple theoretical framework. We use a firm-level panel data for the manufacturing sector in Tunisia to investigate whether adoption of ICT influences efficiency in factors use. We consider the technical efficiency in a production unit which actually refers to the achievement of the maximum potential output given the amounts of factor inputs (taking into account physical production relationships). The analysis is conducted through the use of a parametric method to measure technical efficiency. We estimate a stochastic production frontier and the relationship aimed to explain technical efficiency differentials in a single stage as suggested by Battese and Coelli (1995).

Improving the understanding of the ways in which ICT affect firms' efficiency and economic performance remains important. How and in what measures do ICT affect economic performance and the efficiency of firms?

Our contribution to these debates is essentially an empirical issue. The analysis of a Tunisian firm's data may be viewed as an attempt to apprehend how technical efficiency in Tunisia, a developing country, is being adjusted to the ICT adoption.

Most studies on the economic impact of ICT focus mainly on a limited number of developed countries. Most of these studies have been undertaken to analyze productivity gains of the economy at large or at the sectorial level, but few studies have tried to analyze the impact of ICT at the firm level. Very few studies have tried to analyze the impact of ICT on the economies of developing countries. The main reason is that the underlying data necessary to carry out these studies is not available (Abdelkader, 2006). Available data on ICT adoption is still rough estimates in developing countries, especially at the enterprise level. The debate on the impact of ICT on productivity is still open with regards to developing countries.

Tunisia is among the countries that encourage the diffusion of utilization of ICT. Numerous measures have thus been taken towards further adoption of ICT. Websites e-mail and mobile phones are now widely used in different areas. Between 1998 and 2003, the use of information technologies increased at a tremendous rate. Latest estimates indicate that the number of internet users increased from 70,000 in 1998 to 630,000 in 2003 in Tunisia. The number of mobile phone subscribers increased from 30,600 in 1998 to 1,810,700 in 2003. Despite that, the diffusion appears significantly lower than other advanced countries (Table 1). The penetration of PC's per 100 inhabitants in 2003 corresponds to about one sixth of that in Malta and less than half of that in Poland. A similar picture can be observed by considering the other indicators.

These new technologies are particularly adopted by Tunisian manufacturing firms[1] but with different intensity. In fact, a large number of complementary machines and production processes have to be put in place before new technologies could find useful applications.

The cross section dimension of our data covers firms belonging to different activities and using ICT at different levels of intensity. This implies that if ICT use has a significant impact on efficiency then it should be apparent in our data characterized by two dimensions: temporal and individual.

Using a micro-level detail on individual firms, enables us to trace the relationship between changes in ICT adoption and efficiency at firm level. We can then measure the effects of ICT use on the efficiency according to different sectors and types of firms. By using firm-level data we are also able to directly apply a model derived from the firm's production function and to control for unobserved inefficiency**.** Moreover, firm-level analysis may help in distinguishing the impact of ICT from that of other sources of efficiency growth. An index of ICT use is computed in this study through the use of data on computers penetration, internet and phone communications at the firm level.

Explaining how and to what extent ICT adoption impacts efficiency and productivity may help define policies oriented towards fostering growth and the international competitiveness of domestic firms.

The present paper is organized as follows. Section 2 presents some theoretical and empirical arguments about the relationship between ICT use and technical efficiency. Section 3 contains the model specification. Section 4 describes the data. Section 5 presents the empirical results. Section 6 concludes.

2. ICT and Technical Efficiency: Theoretical and Empirical Issues

How precisely does ICT affect the economic performance and the efficiency of firms?

There are several reasons why technical efficiency, productivity and growth may change when there is change in the production technology at the firm level.

In most analysis of ICT use impacts, two effects of ICT on productivity and growth are distinguished. First, as a capital good, investment in ICT contributes to overall capital deepening which provides productive equipment and software to business and therefore helps raise labor productivity. Investment in ICT equipment increases the amount of capital available for labor thus increasing economy-wide labor productivity and is likely to increase economic growth. Second, greater use of ICT may help firms increase their overall efficiency and thus raise Multiple Factor Productivity. Greater use of ICT also contribute to networks effects, such as lower transaction costs and more rapid innovation, which will improve the overall efficiency (Pilat, 2004).

The benefits of ICT for a firm include savings in inputs, general cost reductions, higher flexibility, improvement in product quality, etc (Spyros, 2004).

ICT are intended to help firms acquire the information needed to change the technology of production, optimize the acquisition and use of factor inputs.

[1] No data is available at the manufacturing sector level. Only aggregate data — for all the economy — is available in Tunisia.

ICT also play a key role in increasing the speed of generation, diffusion and use of new knowledge within plants (Milana and Zeli, 2002). The information stimulates the creation of new knowledge by giving firms and innovators fast access to knowledge.

Adopting ICT results in a more effective use of time. They contribute significantly to closing communication gaps, as users and suppliers can now communicate easier and faster, through E-mails and websites, when placing orders or sourcing for raw materials (Kajogbola, 2004). ICT save time and space — in the sending and retrieving of information both within and across diverse organizations. ICT provide faster response to market needs and allow more flexibility in product design, production and equipment delivery.

Moreover, ICT facilitate training existing staff on new and sophisticated equipments. It has also led to acquisition of additional capabilities by the employees in these organizations. There are also the sociological and psychological impacts on employees created by these technologies in the workplace. Introduction of ICT applications in a firm has impacts on work-group effectiveness, organizational climate, job satisfaction, personal growth and accomplishment (Lefebvre, 1996). Due to the positive worker incentives created by new organizational forms, performance and efficiency increase.

However, several empirical studies suggest that the impact of ICT depends on a range of complementary investments and factors, such as the availability of skills in the firm, and organizational factors (Pilat, 2004). The greatest benefits from ICT are realized when ICT investment is combined with other organizational changes and human capital upgrading. Computer-based technologies are often used by workers with higher skills. Availability of know-how and qualified personnel is a precondition for the use of ICT; for example training in problem-solving, statistical process controls and computer skills can increase the benefits of ICT (Spyros, 2004).

The firm-level evidence also suggests that the uptake and impact of ICT differs across firms, varying according to some firm's characteristics such as the size of the firm, the age of the firm, activity, etc…(Pilat, 2004).

3. Methodology

A number of alternative methods have been proposed to measure technical efficiency of production units. Among these, the application of stochastic frontier productions developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van Der Broek (1977).

In this paper, the stochastic frontier model proposed in Battese and Coelli (1995) is applied to measure the impact of ICT on technical efficiency at the firm level. This model has a merit over other frontier techniques in that it allows tracing the determinants of efficiency using a one stage approach rather than the traditional two stage approach[2]. The impacts of ICT are estimated by their contributions towards enhancing the efficiencies in the utilization of existing factor inputs and technology. A set of firm's characteristics is used to explain technical efficiency differentials among firms, including an index of ICT adoption.

[2] With the traditional two stage approach, efficiency is estimated in stage one and its determinants are identified in stage two by regressing the predicted efficiency scores, obtained in stage one, on some explanatory variables. This two stage approach presents some problems: efficiencies obtained from stage one are assumed to be normal, independent and identically distributed. However, when these efficiencies are regressed in the second stage, it is assumed that the efficiency scores are not identically distributed (Pitt and Lee 1981). Second, the predicted efficiency scores, obtained from the first stage, varies between zero and one, thus traditional econometric methods (least squares or generalized least squares) used in stage two are not consistent. With the one stage approach of Battesse and Coelli (1995), the coefficients of the stochastic frontier and the inefficiency determinants model are estimated simultaneously using maximum likelihood method which gives consistent estimations.

The general form of the stochastic frontier production model for each firm i at time t is defined as:

$$y_{it} = f(X_{it}, \beta)\exp(V_{it} - U_{it}) \tag{1}$$

Where y_{it} denotes the output of the i th firm at the t th time period; X_{it} is a vector of input quantities (capital K_{it} and labor L_{it} inputs are considered in this study); β is a vector of unknown parameters to be estimated. V_{it} is an independently and identically distributed $N(o, \sigma_v^{2})$ random error; and the U_{it} is a non-negative random variable, associated with technical inefficiency in production. Technical inefficiency (TE) is a measure of the discrepancy between a firm's actual output and its optimal (the maximum from the inputs used). It measures the ability of the firms to obtain maximum output from the inputs used. The technical inefficiency of production for the i th firm at the t th period is defined by the ratio of observed output to the frontier output[3] as follows (Ajibefun 2008):

$$TE_{it} = \exp(-U_{it}) = \frac{y_{it}}{f(X_{it}, \beta)e^{V_{it}}}. \tag{2}$$

The prediction of the technical inefficiency is based on its conditional expectation and it is calculated after the estimation of the coefficients β and prediction of V_{it} (Battese et Coelli 1995).

The technical inefficiency factor U_{it} is assumed to be independently and identically distributed, truncations (at zero) of the normal distribution with mean $Z_{it}\delta$ and variance σ_u^{2}, Z_{it} is a vector of variables associated with technical inefficiency and δ is a vector of unknown parameters to be estimated. The technical inefficiency could be expressed as:

$$U_{it} = Z_{it}\delta + w_{it} \tag{3}$$

Where w_{it} is a random variable defined by the truncation of the normal distribution with zero mean and variance σ_u^{2}, such as $w_{it} > -Z_{it}\delta$. In this paper, Z_{it} includes an index of ICT adoption (ICT_{it}) and some others firm's characteristics as whether or not the firm is an exporting one X_i, the foreign capital participation, the firm size, and whether or not the firm is a private one.

The "size" variable is a dummy variable for small and medium sized enterprises (employing from 20 to 99 workers) and large enterprises (employing over 99 workers). The "ownership" variable is also a dummy variable for private (1) and public firms. The foreign capital participation "foreign" variable is the percentage of foreign capital participation. The exporting rate is the percentage of foreign sales.

To take account of a possible complementary relation between ICT use by firms and their level of skill (or human capital), the basic model was augmented. The ICT variable, in addition to being entered individually, was interacted with human capital factor to take account of the proposition that for firms to achieve improvements through the use of ICT

[3] The frontier output is given by the production frontier ($f(X_{it}, \beta)e^{V_{it}}$) which gives maximum output from a given quantity of inputs. It is possible that a firm could not reach the frontier. The gap between the observed output and the maximum output obtainable from inputs measures inefficiency.

they must possess skill advantages. The human capital factor "qualification" is measured by the ratio of skilled to unskilled labor in a firm.

Identification of sources of inefficiency from equation (3) is important to improve performance and to close the gap between actual and potential output.

The Cobb-Douglas form was chosen to characterize Tunisian manufacturing technology. In fact, the data used don't reject the Cobb-Douglas specification[4]. The Cobb-Douglas functional form has been shown to be theoretically sound and attractive due to its computational feasibility. Moreover, a few studies examining the impact of the functional form on efficiency have shown that the functional specification does have a significant impact on estimated technical efficiency[5] (Sharma and Leung, 2001).

4. Data and Descriptive Analysis

The data used in this study is taken from the National Annual Survey Report on Firms (NASRF) carried out by the Tunisian National Institute of Statistics (TNIS). The data covers firms from different manufacturing sectors over the period 1998-2002. The survey looks at economic accounts of enterprises and at some ICT use indicators, such as hardware and software investment at the firm level.

In the first stage, the dataset was "cleaned" from observations which could be seen as erroneous or which were clearly outliers. Our empirical analysis is based on an unbalanced panel consisting of a sample of 1824 firms from the agro-food (IAA), the chemical (ICH), the ceramic (IMCCV), the diverse (IMD), the electric (IME) and the textiles, wearing, leather and footwear (ITHC) industries (see Table 2). These firms are observed from between 1 and 5 annual observations over the period 1998-2002. The firm's activity is described by a one-digit Tunisian nomenclature of economic activities which leads to the above six manufacturing sectors.

The dataset includes: value added (y) measured in constant prices, capital stock (K) evaluated at historical values[6], labor (number of employees L), a decomposition of labor into skilled (L^1) and unskilled labor (L^2). The activities of unskilled workers include machine operation, production supervision, repair, maintenance and cleaning. The activities of skilled workers include management, administration, and general office tasks. This is nearly the production/non-production classification for unskilled/skilled workers. The number of employees is adjusted according to whether it is part or fulltime equivalent employment. We also have information about some time-invariant firm characteristics such as the sector of activity, and whether or not the firm is an exporting one.

Since we are dealing with a pooled sample of individual firm data, the issue of firm heterogeneity is an important one. In our sample, heterogeneity can result from the fact that firms in different sectors of the industry can be expected to operate under different technologies which leads to differences in the stochastic production frontier. We introduce sector-dummies into the meta-production frontier to account for these sector-specific differences.

4.1. ICT index:

The data includes some ICT investment variables; we use this data to construct an ICT index (ICTI) as a measure of ICT adoption at the firm level. We construct the ICTI from three ratios. The names and definitions of these ratios in the index are given below:

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[4] A Cobb-Douglas versus a translog specification will be tested in the empirical investigation (see paragraph 4).

[5] A translog production function will be also tested in the empirical analysis.

[6] Capital stock is measured at constant prices, deflating the historical acquisition prices to a common base year.

Ratio 1: Communication ratio: communication expenses /total expenses on external services.

Ratio 2: Hardware acquisitions ratio: hardware acquisitions/ total acquisitions of tangible immobilizations.

Ratio 3: Software acquisition ratio: software acquisitions / total acquisitions of intangible immobilizations.

For the construction of an ICT index, we use a simple average of these components which gives a numerical score for each firm in each year as follows[7]:

$$ICTI=1/3(Ratio1+Ratio2+Ratio3) \quad (4)$$

Our index measures the intensity of use of important technologies such as internet, mobile phones and PC penetration. It measures the ICT use for firms on an annual basis over the period 1998-2002. The same ratios are used to calculate the index in every year and for every firm. Our index is explicitly designed to be comparable across time and firms.

Table 3 provides some descriptive statistics for the ICTI and its components. On average the three ratios and the ICTI are very low. The ICT diffusion in Tunisian manufacturing sector appears weak, on average. But the variance of these indicators are high (relative to the means), which means that these new technologies are adopted by Tunisian manufacturing firms but with very different intensity. This suggests that if ICT have a significant effect on efficiency, it should be apparent in our data characterized by a high variability.

Before analyzing how the use of ICT is related to plant performance, we examine the characteristics of firms that adopt advanced technologies. Table 4 provides the group means and some others descriptive statistics of the ICTC by key characteristics. The significance of the difference in the ICTI between two groups is evaluated by a non-parametric test. It is basically used to test for the equality of group's means for a variable. The testing criterion is the Wilcoxon Lambda (W) (the Mann Whitney test). Table 6 presents the results of the test for different groups.

From the W values given in Table 4, the difference in ICT use is not significant across public and private firms, exporting and locally oriented, national and international firms. But, from this table it emerges that there is difference between the ICT use in large and small firms. The most intensive users of ICT tend to be large firms. Chemical and electric sectors are intensive users of ICT relative to the other sectors. ICT use is relatively low in agro-food and ceramic industries. The intermediate group consists of such industries as textile and diverse sectors.

A preliminary descriptive investigation of the role played by ICT on the firm's economic performance is done by comparing the economic performance of ICT-intensive firms and non-ICT firms (or of firms that have ICT intensity above and below sectorial average). Table 5 provides the group means of some performance indicators: production growth, employment growth and growth of labor productivity in the firms.

Overall, the evaluation illustrates that ICT-intensive firms show greater economic performance regardless of what growth indicator is employed. ICT-intensive firms grew 0.7 percent faster than non-ICT firms in terms of labor productivity. They also showed a more

[7] I also tried a principal component method to construct the ICT index. This gives different weights for different ratios : ICTI=0.37Ratio1+0.27Ratio2+0.36Ratio3. To compare the index resulting from the two procedures, Spearman rank correlation coefficient is calculated. This correlation is of 0.977 and the association is very strong between the index obtained from a simple average and the index obtained from the principal component procedure. The estimation results will be not sensitive to the index used.

rapid growth in production. Employment decline is more pronounced in enterprises that do not use ICT.

From this table, it emerges that the performance indicators are, on average, higher in the enterprises that use ICT. The data from this table suggests that ICT enhance the economic performance of most firms in manufacturing sector. The magnitude of growth differences between most and least ICT-intensive firms is positive. However, from the W test values given in this table, the difference in performance indicators is not statistically significant across the considered groups. The positive relation between ICT use and superior performance in Tunisia manufacturing sector has yet to materialize using econometric models. To control for the role of other factors, regression analysis has been completed.

5. Econometric Results and Discussion

We consider a meta-production frontier (Leung and Sharma, 2001) — also referred to as an envelope frontier — which is obtained by pooling all the sample observations across sectors. Then the technical efficiency index for each of the sample firms in each sector is estimated relative to a single common efficient or best practice frontier[8]. We introduce sector-dummies into the meta-production frontier to account for sector-specific differences. We also introduce year effects (year dummies) to take into account common aggregate shocks, particularly technological shocks.

The parameters for the stochastic meta-production frontier and those for the technical inefficiency models in equations (1) and (2) are estimated using the maximum likelihood (ML) estimation program frontier 4.1 (Coelli (1994)) which estimates the variance parameters of the likelihood function in terms of $\sigma^2 = \sigma_v{}^2 + \sigma_u{}^2$ and $\gamma = \dfrac{\sigma_u{}^2}{\sigma^2}$. The estimate for the variance parameter γ permits the test of the null hypothesis that the inefficiency effects are absent.

The results relative to the stochastic meta-production frontier are presented in table 6. As shown in these tables, the null hypothesis $\gamma = 0$ was rejected suggesting that technical inefficiency effects are important in explaining the levels and variations in manufacturing production in Tunisia.

A translog versus a Cobb-Douglas specification was tested using an F- test based on the residual sum of squares. The resulting test at the 5% level of significance suggests that the data used don't reject the Cobb-Douglas specification. The restricted form of the translog frontier model in which the second order coefficients are 0 is accepted. The Cobb-Douglas frontier model provides the best fit for the data and adequately represent the data.

The output elasticities have appropriate signs and significant values. The capital elasticity is 0.33 while the labor elasticity is around 0.7. These high labor elasticities reflect the high labor-use intensity in Tunisian manufacturing.

As mentioned earlier, inter-sector differences were accounted for by including the sector-specific dummy variables in the meta-production frontier model. The effects due to differences in resource endowments and other economic environments are captured by these dummies (Gunaratne and Leung, 2001). Thus, the coefficients associated with these dummy

[8] To provide comparable technical efficiency scores for firms across different sectors, we estimate by the maximum likelihood method a single frontier ($f(X_{it}, \beta)e^{V_{it}}$), which gives the best practices (the maximum output) for firms. The parameters of this frontier are estimated using data from firms in all sectors; we don't estimate different frontiers for firms across different sectors.

variables indicate differences in performance relative to the reference sector. Textile is treated as the reference sector within the meta-production frontier framework[9]. The coefficients associated with sector dummies are statistically significant confirming the presence of inter-sectors differences in production. Chemical and electric sectors were found to be superior to the rest of sectors in terms of productivity.

The results indicate that the variables included in the technical inefficiency model contribute significantly to the explanation of technical inefficiencies. The effect of ICT use on technical inefficiency (technical efficiency) is reflected by the coefficient of the ICTI variable which is negatively (positively) significant at 5% level. A clear positive relationship was found between the efficiency and the ICTI variable. ICT, by exposing firms to greater information on product characteristics, updated technologies and market trends, provide companies with learning opportunities that allow them to get on a steeper learning curve than firms that do not use ICT. This is in accord with our expectation.

The coefficient of the interaction term of the ICTI with the human capital variable is negative and statistically significant. This result can be interpreted as a sign for the existence of complementarities between ICT and human capital. This means that the combined use of ICT and human capital in a firm would enhance its efficiency beyond the direct effects of these factors taken alone.

The results reveal a positive and significant relationship between exporting rate and technical efficiency. Firms with high foreign capital participation are more efficient than those with low foreign capital participation. Participating in export market and developing partnerships with foreign investors brings firms into contact with international best practices and fosters learning, and efficiency growth. Small and medium firms, defined here as those with 200 or less employees, are less efficient than large ones. The dimensions of the enterprises affect their performances. This confirms the fact that scale inefficiency is a serious problem in developing countries, especially in Tunisia. The results obtained by distinguishing private from public firms suggest that efficiency, *ceteris paribus*, do not vary across private and public firms.

5.1. Technical Efficiency

Table 7 reports the mean efficiency obtained from the meta-frontier by key characteristics of firms. The results confirm the previous results[10]. We find that firms that have a relatively intensive use of ICT are, on average, 5 % more efficient than those that do not.

The exporting firms are, on average, the most efficient. Firms with high foreign capital participation are 13% more efficient than those with low foreign capital participation. Larger firms are more efficient than smaller ones due to better organization.

The technical efficiency ranges from 0.68 for the agro-food and ceramic to 0.72 for the ITHC sector. Electric and textile show the highest efficiencies on average. The overall mean value of 71 % indicates that firms, near the average, can improve their output level by 30 % with the same set of inputs. These results indicate that there are substantial technical inefficiencies in Tunisian manufacturing.

Efficiency increased, on average, during the period 1998-2002 from 0.66 in 1998 to 0.72 in 2002. This increase could be explained by the fact that during this period, and since 1996, the Tunisian government had been adopting an active liberalization program. The reduction or

[9] The importance of ITHC industry in Tunisian manufacturing sector is a reason for treating it as the reference sector. It is a key industry which is essential for employment and for export.

[10] The efficiency measures are very similar when a translog function is used; our results are robust to different specifications.

elimination of tariff and non-tariff barriers increases the competition that domestic producers face as a result of imported goods. Nonetheless, in raising the level of competition to which domestic products are subjected to in home markets, imports provide incentives for firms to improve their operations. Moreover, in response to competition in foreign markets, exporting firms try to keep up with modern technology in order to maintain or improve their market position. This provides a stimulus and opportunity to increase efficiency and thus productivity. The exposure to trade, or increases to this kind of exposure, forces the least efficient firms out of the industry. These trade induced reallocation towards more efficient firms explain why trade may generate aggregate efficiency gains without necessarily improving the productive efficiency of individual firms.

6. Conclusion

The purpose of this paper is to examine the extent to which the use of ICT has contributed to efficiency growth in Tunisian manufacturing firms and how this varies according to the roles played in different branches. We use a firm-level panel data for the manufacturing sectors in Tunisia to investigate whether adoption of ICT impacts on efficiency in factors use. We principally adopt the stochastic frontier approach. We estimate a stochastic production frontier and the relationship aimed to explain technical efficiency differentials in a single stage.

The results indicate that there are substantial technical inefficiencies in the Tunisian manufacturing sector. Given the existing technology, the firms could increase their production by around 30% using their existing resources more efficiently.

Our results are in line with prior expectations on the impact of ICT use on efficiency. The results have confirmed the presence of positive returns to ICT capital. We have found that the impact of ICT on efficiency is strong. Firms that have a relatively intensive use of ICT are, on average, 5 % more efficient than those that do not.

Further progress in ICT adoption could be considered as a strategic policy oriented towards fostering growth. Tunisian firms operate below the “world technology frontier”, then substantial efficiency gains can be achieved by adopting the technologies already in use in advanced countries.

Our results also suggest that it is important to carefully control for human capital related characteristics of employment when studying the effect of ICT. The evidence shows that achieving benefits from investment in ICT requires complementary investments and changes in human capital. This means that the combined use of ICT and human capital in a firm would enhance its efficiency beyond the direct effects of these factors taken alone.

The micro analysis conducted in this paper supports the view that Tunisian manufacturing could derive more productivity gains from the use of ICT. Production of ICT equipment is not necessary to access ICT-related productivity gains.

The results also reveal a positive and significant relationship between the exporting rate and technical efficiency. Firms with high foreign capital participation are more efficient than those with low foreign capital participation. Participating in export markets and developing partnerships with foreign investors brings firms into contact with international best practices and fosters learning and efficiency growth. Small and medium firms are less efficient than large ones. The dimensions of the enterprises affect their performances. This confirms the fact that scale inefficiency is a serious problem in developing countries, especially in Tunisia.

Efficiency increased during the period 1998-2002 from 0.66 in 1998 to 0.72 in 2002 on average. This increase could be explained by the fact that during this period, and since 1996, the Tunisian government had been adopting an active liberalization program. Increased openness modifies the production technology available through increased imports of advanced capital goods and technology, or through opportunities for exporters to learn from foreign buyers and from being exposed to foreign markets. Liberalization may also affect the efficiency with which firms use factors; greater competition from imports induces greater efficiency.

However, our study suffers from lack of ICT-adoption data. The current available datasets on ICT use are still rough estimates of Tunisian manufacturing, especially at the firm level. Potential biases that result from the lack of data — on the intensity of ICT use in firms — may be checked in future research. New indicators on emerging technologies have to be developed to satisfy new users' needs. Tunisia has to fill all the information gaps associated with measuring the intensity of use of ICT at the firm level. A survey on the use of ICT by enterprises needs to be conducted.

References

Abdelkader, Khaled, (2006). "The Impact of ICT on Economic Growth in MENA Countries", European University Institute, Working Paper RSCAS n°2006/31.

Aigner, D.J., Lovell, C.A.K. and Schmidt, P.J., (1977). "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics* 6, 21-37.

Ajibefun, Igbekele A. "Technical Efficiency Analysis of Micro-Enterprises: Theoretical and Methodological Approach of the Stochastic Frontier Production Functions Applied to Nigerian Data." Journal of African Economies. Volume 17 #2 March, 2008. pp. 161-206.

Baldwin, J.R and D.Sabourin, (2001). "Impact of the Adoption of Advanced Information and Communication Technologies on Firm Performance in the Canadian Manufacturing Sector", WP, Statistics Canada.

Battese, G.E and Coelli, T.J., (1995). "A Model for Technical Inefficiency in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics* 20, 325-332.

Coelli, T.J., (1994). "A Guide to Frontier Version 4.1: A Computer Program for Stochastic Production and Cost Function Estimation", Department of Econometrics, University of New England, Armidale, Australia.

Gunaratne, H.P.Lokugam and PingSun Leung, (2001). "Asian Black Tiger Shrimp Industry: A Meta-Production Frontier Analysis", Economics and Management of Shrimp and Carp Farming in Asia, A collection of research papers, Editors, Network of Aquaculture Centers in Asia-Pacific.

Kajogbola, O. David, (2004). "The Impact of Information Technology on the Nigerian Economy: A Study of Manufacturing and Services Sectors in the South Western and South Eastern Zones of Nigeria", ATPS (African Technology Policy Studies) Working Papers Series n° 39.

Lefebvre, Elizabeth, and Louis Lefebvre, (1996). *Information and Telecommunication Technologies, the Impact of their Adoption on Small and Medium-Sized Enterprises*. The International Development Research Center (IDRC), Canada.

Leung, Pingsun and Kheun.R. Sharma, (2001). "Technical Efficiency of Carp Pond Culture in South Asia: An Application of a Stochastic Meta-Production Frontier Model", Economics and Management of Shrimp and Carp Farming in Asia, A collection of research papers, Editors Network of Aquaculture Centers in Asia-Pacific.

Meeusen, W. and Van Der Broek, J., (1977). "Efficiency Estimation for Cobb-Douglas Production Functions with Composite Error", *International Economic Review* 18, 435-444.

Milan, Carlo and Alessandro Zelli, (2002). "The Contribution of ICT to Production Efficiency in Italy: Firm-Level Evidence Using Data Envelopment Analysis and Econometric Estimations", STI Working Paper 2002/13, OECD.

Pilat, Dirk, (2004). "The Economic Impacts of ICT- A European Perspective", paper presented to the conference on IT innovation, Tokyo, December 2004.

Pilat, Dirk, (2004). “Introduction and Summary” in The Economic Impact of ICT Measurement, Evidence and Implications, OECD, France.

Pitt, M.M. and Lee M.F., (1981). “The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry”, *Journal of Development Economics* 9, 43-64.

Spyros, Arvanitis, (2004). “Information Technology, Workplace Organisation, Human Capital and Firm Productivity: Evidence for the Swiss Economy”, in The Economic Impact of ICT Measurement, Evidence and Implications, chapter 9 OECD, 2004.

World Bank, 2006, “Information and Communications for Development 2006: Global Trends and Policies”, www.worldbank.org.

Table 1: ICT Indicators: An International Comparison (2003)

	Mobile phone (per 100 inhabitants)	Internet (per 10000 inhabitants)	PC's penetration (per 100 inhabitants)
Tunisia	**19.21**	**637.01**	**4.05**
Morocco	24.34	265.57	1.99
Egypt	8.45	393.31	2.19
Algeria	4.56	159.78	0.77
Jordan	24.18	833.91	3.75
Poland	45.09	2324.5	10.56
Romania	32.87	1905.27	8.30
Turkey	40.84	805.46	4.46
Malta	72.5	3030.3	25.51

Source: Union Internationale des Telecommunications.

Table 2: Number of Firms by Industry

Industry	IAA	IMCCV	IME	IC	ITHC	ID	Total
Number of Firms	253	164	267	201	703	236	1824

Table 3: Descriptive Statistics of the Index and Its Components

Variable	Obs.	Mean	Std. Dev.	Min	Max	Max	Q3
Ratio 1	3956	0.037	0.052	0	0.68	0.023	0.052
Ratio 2	3956	0.037	0.13	0	1	0	0.004
Ratio 3	3956	0.13	0.33	0	1	0	0
ITIC	3956	0.0683784	0.1221917	0	0.6850936	0.014	0.041

Notes: Ratio 1: Communication ratio; Ratio 2: Hardware acquisitions ratio: hardware acquisitions/ total acquisitions of tangible immobilizations; Ratio 3: Software acquisition ratio: software acquisitions / total acquisitions of intangible immobilizations.

Table 4: Descriptive Statistics of ITIC by Key Characteristics

	Mean	Std	Min	Max	Mann Whitney
i) By size					**-5.52 (p=0.00)**
Small and Medium	0.062	0.11	0	0.68	
Large	0.1	0.14	0	0.59	
ii) By Ownership					**1.23 (p=0.21)**
Private	0.065	0.11	0	0.68	
Public	0.077	0.13	0	0.58	
iii) By Exporting or Domestically Oriented					**-0.65 (p=0.51)**
Exporting firms	0.07	0.12	0	0.68	
Domestically oriented	0.067	0.12	0	0.51	
iv) By National or International Firms					**0.7 (p=0.48)**
National	0.067	0.12	0	0.68	
International	0.07	0.12	0	0.51	
v) By sector					
IAA	0.047	0.1	0	0.59	
IMCCV	0.058	0.11	0	0.39	
IME	0.088	0.13	0	0.47	
ICH	0.078	0.12	0	0.52	
ITHC	0.066	0.12	0	0.68	
ID	0.072	0.12	0	0.58	

Table 5: Group Means of Production, Employment and Labor Productivity Growth

Performance Indicators	Enterprises that Intensively Use ICT	Enterprises that Don't Intensively Use ICT	Mann Whitney
Production Growth in %	0.0022	0.0077	-0.727 (p=0.46)
Employment Growth	-0.0016	- 0.0001	-0.16 (p=0.86)
Growth of Labor Productivity (value added per worker)	0.0022	0.0093	-0.57 (p=0.56)

Table 6: Maximum Likelihood Estimates of Stochastic Frontier with Sectors and Year Dummies and Technical Inefficiency Model for Tunisian Manufacturing

Variables	Coefficients	Std Dev	T
Production Frontier			
Constant	5.5	0.066	83.4
Ln(Labor)	0.71	0.012	58.03
Ln (Capital)	0.33	0.0075	43.93
Dummy IAA	0.28	0.034	8.3
Dummy ICH	0.34	0.036	9.6
Dummy IMCCV	0.097	0.039	2.45
Dummy ID	0.26	0.033	8.01
Dummy IME	0.32	0.032	10.07
Technical Inefficiency Model			
Constant	-3.43	0.43	-7.8
ICTI	*-3.67*	*0.35*	*10.25*
*ICTI*Qualification*	*-9.9*	*0.93*	*-10.63*
Exporting Rate	-0.48	0.1	-4.5
Foreign Participation	-0.48	0.0035	-13.6
Ownership (private dummy)	0.52	0.28	1.84
Size (large dummy)	-0.129	0.1	-1.2
Variance Parameters			
σ^2	2.5	0.17	12
γ	0.87	0.011	78
Log (likelihood)	-3768,18		
Mean of Efficiency	0.71		

Table 7: Descriptive Statistics for Technical Efficiency Scores by some Firms' Characteristics

	Mean	Std	Median	Min	Max
i) By ICT Using Level					
High	*0.72*	0.12	0.75	0.016	0.92
Low	*0.67*	0.14	0.70	0.016	1
ii) By Exporting or Domestically Oriented					
Exporting firms	0.76	0.11	0.78	0.05	1
Domestically oriented	0.68	0.13	0.72	0.016	0.92
iii) By Ownership					
Private	0.7	0.13	0.72	0.016	0.92
Public	0.8	0.09	0.82	0.05	1
iv) By Foreign Capital Participation					
High participation	*0.81*	0.07	0.82	0.05	1
Low participation	*0.68*	0.13	0.72	0.016	0.92
v) By size					
Large	0.76	0.11	0.79	0.069	0.92
Small and medium	0.7	0.13	0.73	0.016	1
vi) By year					
1998	0.66				
1999	0.71				
2000	0.71				
2001	0.72				
2002	0.72				
vii) By Sector					
IAA	0.68				
IMCCV	0.68				
IME	*0.71*				
IC	0.69				
ITHC	*0.74*				
ID	0.69				