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Human capital and productive efficiency of Senegalese companies: estimation through the stochastic border approach

Abstract

In this paper, we studied the productive efficiency of Senegalese companies; a source of economic growth and development. These education providing companies in the primary, secondary and tertiary sectors mainly contribute to the value added, gross domestic product and employment and contribute to social cohesion. To measure this, we used the stochastic approach proposed by BATTESE & COELLI (1995) to analyze the productive efficiencies of traditional and modern companies in Senegal. The objective of this study is to assess their efficiency based of the control variables that characterize them. Such variables include transport expenditure, fixed investment, technology expenditure, company experience, company manager's level of education, and employees 'level of human capital. It also examines the impact of company size, company status, and the origin of capital on the firms' efficiency.

Key Words: *effectiveness; productivity; efficiency; Senegal*

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1. Introduction

The efficiency of firms in sub-Saharan African countries has great importance in the empirical literature. Companies in these countries generally operate well below the possible technological efficiency. Because they have low yields, it is difficult for them to absorb economic shocks that can jeopardize their existence and have negative consequences on the country's growth and employment. Consequently, these companies must have at their disposal measurement tools that allow them to quantitatively assess their levels of economic efficiency.

In the context of the Senegalese economy, companies are exposed to shocks such as power cuts, strikes, etc. These shocks cannot be controlled, at least in the short term, by managers. The stochastic border, which considers factors that cannot be controlled by the manager, is an ideal parametric method for measuring efficiency. The frontier estimation of economic efficiency in a formal and clear way was mainly developed by FARELL (1975). According to this author, the objective of any company must be to estimate the best practice in its production activity, taking into consideration the available data. The estimation of this practice requires the measurement of effectiveness. In the literature, there is a second non-parametric method for evaluating this effectiveness.

The parametric approach estimates the parameters of the boundary defined and specified by an analytical function, from the tools of econometrics and statistics and those of linear programming. Its main limitation is that reference can easily be made to only one objective variable; that is, only one criterion for measuring effectiveness. On the other hand, for the non-parametric method, a priori no particular form of function is specified at the border. What remains to be specified are the properties that must be satisfied by all production (TAFFE, 1998).

This parametric approach also uses, as the first one, the tools of linear programming.

In the case of our study, as we specify, the stochastic parametric method is used to estimate the productive efficiency of Senegalese firms. However, it should be noted that there is a parametric technique known as deterministic that will not be studied in this work, as it attributes the border gap only to factors that are under the control of the manager. As a result, it neglects the possibility that a company's performance may be affected by several factors beyond its control. The stochastic parametric approach therefore offers us a broader view of the evaluation of the effectiveness of Senegalese firms, because it controls elements such as the size of the firm, the formal or informal nature, the origin of the capital, the effect of which is as important as the factors controllable by the firm. Our objective is to estimate the productive efficiency of Senegalese companies in the modern and traditional sectors using endogenous variables and those out of control using the stochastic approach.

This type of use of the stochastic approach has been used in many empirical studies. Indeed, in the early 1980s, LEE & PITT (1981) estimated the level of technical efficiency of 50 Indonesian companies specializing in heavy industry. Like the initiators of the approach, MEUSEN & Van Den BROECK (1977) applied technical efficiency measurement to 10 French industrial sectors. AIGNER & al. (1977) and LEE & TYLER (1978) also used this approach to analyze the US agricultural sector and Brazilian manufacturing industry respectively. On American companies producing electric generators, KOPP & SMITH (1980) apply this stochastic approach. Despite the use of this approach by many authors, including those we have cited to analyze the effectiveness of companies, limitations have been identified in its application. Indeed, as FORSUND & al. (1980) noted, the initial approach to this stochastic boundary does not allow the two components to be differentiated for each company. The technique only allows the

calculation of the average efficiency level for the entire sample; therefore, the average of all companies. In response to this limitation, several extensions of this stochastic boundary model have been proposed. JONDROW & al (1982) showed that by assigning known distributions to the two components of the error term a priori, it is possible to differentiate them and obtain an efficiency measure for each company. We can also mention the KUMBHAKAR (1988, 1989) and BATTESE & COELLI (1988, 1992, 1995) models. The stochastic parametric approach proposed by the latter postulates that the error term is composed of two independent parts: a purely random component (v) that is found in any relationship between factor and effect and that is distributed on either side of the production boundary and a component representing technical inefficiency (μ) and that is distributed on only one side of the boundary.

In the context of inefficiency, we use World Bank survey data on Senegalese companies that respond to this point. The stochastic production boundary model of BATTESE & COELLI (1995) will serve as a reference framework.

2. Literature review

The theoretical hypothesis that human capital is a key determinant of productivity has received considerable attention in the empirical literature. Since BECKER (1964), human capital has been considered as a source of productive efficiency and increased future income. Empirical studies by DENISON (1962), JORGENSON & GRILICHES (1967) found that the impact of human capital on productivity is positive. KRUEGER (1968), for his part, makes a comparative analysis between the United States, Canada and twenty developing countries by estimating the inefficiency of production when there is a difference in the availability of human capital stock. Despite the fact that data on factors of production in developing countries are difficult to access and unreliable, he has come to some very interesting results. Based on the assessment of marginal factor productivity in

the United States, KRUEGER (1968) adds to this production gap due to the low accumulation of human capital in developing countries. The per capita income that can be achieved in these countries is reduced to at least to 3.7% on the average because of insufficient investment in education. But HALL & JONES (1999) argue that human capital explains little of the differences in productivity between countries. PRITCHETT (2001) says that the relation between education and growth may be limited because of the poor quality of education in some countries specially in Subsaharan Africa. Indeed, using international data to compare production levels across a wide range of countries, they find that differences in human capital explain some, but not all, of the large variation in per capita production levels, thereby rejecting the issue of the poverty trap. CASELLI & COLEMAN II (2006) contradicts the conclusions of JONES (1999). For them, what explains the differences is not the total productivity of factors, but rather the use of labor efficiency. They conclude that it is the efficiency with which skilled labor is used that explains the differences in income between countries.

Insufficient human capital efficiency could jeopardize this predicted economic catch-up and plunge these countries into a "poverty trap". To get out of this situation, we need to invest more in education, improve the use of human capital, and therefore its effectiveness, as well as its quality, in order to achieve sustainable economic growth.

The empirical conclusion of NELSON & PHELPS (1996) approach is that the productivity growth rate is positively correlated with the level of education, particularly with the number of individuals in secondary and higher education. ENGELBRECHT (1997) also observes significant effects of education on growth in OECD Member countries. His empirical model takes into account the effects of R&D expenditures and is evaluated using the teaching statistics from BARRO & LEE (1993) for the population aged 25 and over. Again, these results suggest

that productivity growth is related to the increase of the average number of years of study, as we would expect if the microeconomic estimates of study performance reflected a real effect on productivity. In a separate set of estimates, ENGELBRECHT also finds support for the idea that educational attainment plays a role in technological catch up. He finds that productivity increases faster in countries with higher average educational attainment.

BENHABIB & SPIEGEL (1994) find that the number of students in secondary and higher education has a significant influence on the productivity growth rate. On the other hand, in another study conducted the same year, covering 78 countries during the period 1965-1985, they found that education does not have a direct effect on productivity growth but an indirect effect through its influence on the rate of innovation and the speed of technological catch-up on the other.

For SCHULTZ (2003), human capital inputs were recognized as critical factors in achieving recent sustained productivity growth in some African countries, while MOOCK (1981), already estimated that education could improve technical efficiency directly through improving the quality of work, increasing farmers' ability to adapt to imbalances, and through its effect on the use of inputs. As regards GOKCEKUS & AL. (2001), they explore the relationship between human capital and efficiency: the role of education and experience in microenterprises in the wood products industry in Ghana. Improving efficiency and creating new jobs through microenterprises provides viable solutions to four problems in developing countries: unemployment, rural exodus, inefficient use of resources and lack of international trade capacity. While, MAUDOS & al. (1998) analyze the role of human capital in productivity gains in OECD countries during the period 1965-90, breaking down productivity gains from technological progress and efficiency gains. To this end, they use the stochastic boundary

production function and a nonparametric approach and calculate the MALMQUIST productivity indices. Investment in education and skills is at the heart of innovation and, at the very least, facilitates the introduction of new technologies and new forms of work organization and thus improves productivity (OECD, 2005).

Other studies have looked at the composition of human capital, i.e. the level of education in primary, secondary and higher education (VANDENBUSSCHE & al., 2006; ANG & al., 2011). The study by VANDENBUSSCHE & al. (2006) showed that the growth in growth in OECD countries relates more to that of skilled human capital (higher education) than unskilled ones (primary and secondary education). The authors interpreted these results to mean that human capital contributes to productivity growth through innovation channels in OECD countries. However, ANG & al. (2011) have shown that human capital (skilled or unskilled) contributes neither to innovation nor to the adoption of technology in the context of low-income countries. In their work on developing countries authors such as ROSHOLM & DABALEN (2007). The authors apply matching techniques to estimate the effects of training provided in African firms, particularly those in the formal sector in Kenya and Zambia. They find a positive return of around 20%. This result is higher with a long training period in large firms. In Kenya the returns from formal training are higher than those from informal training, while the reverse is observed in firms in Zambia. Similarly, in a study on the efficiency of Arabica coffee production in Cameroon, NCHARE (2007) concludes that a variable like education negatively influences technical efficiency. These results are based on the premise that human capital formation improves resource use and productivity of rural households (SOLIS & AL., 2009).

Many studies indicate a positive relationship between education and productivity for developing and developed countries. Some studies show that the number of schooling years or the completion rate of secondary and tertiary education is

important in explaining the improvement of TFP for many countries (BENHABIB & SPIEGEL 2005; BRONZINI & PISELLI 2009; EROSA, KORESHKOVA & RESTUCCIA 2010).

DE LA FUENTE (2011) predicted that models of human capital and productivity are built around the hypothesis that the knowledge and skills embodied in human capital directly raise productivity and increase an economy's ability to develop and to adopt new technologies. The further a state is from the frontier, the greater the benefits of this catch-up.

BENHABIB & SPIEGEL (1994) noted that a more educated labor force would also innovate faster. However, on the contrary, CARDERELLI & LUSINYAN (2015) postulates that marginality and negative signs of total factor productivity are indications of inefficiency, poor economic performance, underuse of allocated resources, weaker innovation and technological process. In summary, human capital theoretical models are premised on the postulation that the embodiment of skills and knowledge of human capital directly raises productivity, leading to the adoption of new technologies and improved economic performance. However, it appears that the empirical evidence has not always been consistent with this theoretical model. Moreover, there is insufficient empirical evidence to test this assumption in SSA countries. The negative results reported in some studies have led scholars to question the functional role of higher education in the productivity process.

Otherwise that there might be a link between workforce skills and education and the productivity of the enterprise is to be expected. A worker with more education is expected to contribute more to enterprise productivity than uneducated or unskilled workers. Some of the more revealing results relate to what type of education or training contributes most to productivity and whether there are important sector differences. Studies can be divided between those that use in-service training as the human capital variable and those that use educational attainment. The

choice of which variables to focus on is often determined by the variables that are available in enterprise datasets. Along with issues of variables, there are also questions of the estimation techniques used and whether they are capturing a legitimate correlation. The literature includes studies of firms of all sizes and others that focus specifically on SMEs. Generally, micro-level analysis of the relationship between education and training and enterprise performance is fairly recent. Only 2 decades ago, BLACK & LYNCH (1996, p. 263) would assert that there have been "few studies" in the United States (US) testing the impact of "education and employer-provided training on productivity." A decade later, DEARDEN & al. (2005) would still argue that despite the interest by policy makers in the United Kingdom (UK), there "are hardly any papers that examine the impact of work-related training on direct measures of productivity. " In the same vein, ZWICK (2006, p. 27) noted that the evidence of the link between training and productivity effects is "thin and partly contradictory ». Furthermore BLACK & LYNCH (1996) found a significant and positive impact of education level on enterprise productivity for both the manufacturing and nonmanufacturing sectors, using data from the US. Furthermore, the total number of workers receiving enterprise training did not affect productivity, although more detailed analysis showed that in service but off-the-job training for manufacturing workers and computer-based training of nonmanufacturing workers was correlated with higher productivity. The study also found that off-the-job training was less disruptive of the production process and could generate better outcomes. HALTIWANGER & al. (1999) found clear evidence that enterprises with more educated workers are more productive. The results, based on data from the US state of Maryland, suggest that "high-productivity workplaces are also high-skill workplaces" (p. 97).

DEARDEN & al. (2005) found a statistically significant impact of training on productivity in the UK. However, the

researchers used a vague training variable from a survey that asked respondents if they had been engaged in any type of work-related education or training over the previous 4 weeks. Nonetheless, an increase in training of 1 percentage point increased production output by about 0.7% —a rather large impact. In a similar study, ZWICK (2006) found that German firms that trained a large share of their workers in the first half of 1997 had higher productivity in subsequent years.

Several studies have focused on Asia. BATRA & HONG (2003) found that formal training is an important determinant of technical efficiency — a measure closely related to productivity. They employ data on a cross-section of SMEs in three countries in Latin America, Indonesia, Malaysia, and Taipei, China. The study also found that the most efficient firms combine formal and informal training but that informal training by itself is negatively correlated with firm efficiency, except in the case of Mexico. The general results confirm the findings of an earlier study (TAN & BATRA, 1995). VU (2003) found that a larger share of skilled workers in the enterprise workforce was correlated with higher technical efficiency of state-owned enterprises in Viet Nam. The two other key factors were engagement in export activities and location in Ho Chi Minh City. HARA (2011) studied the impact of training on the productivity of non regular workers in Japan. Those who received training, both on and off the job, demonstrated higher productivity. Productivity was measured imprecisely as the increase in work assignments, work levels, and work responsibilities. CHAROENRAT & HARVIE (2014) found that the share of skilled workers in small Thai manufacturing firms is positively correlated with technical efficiency. However, the relationship does not hold for medium-sized firms — a puzzling result. Combining small and medium-sized firms, the study does find a significant correlation between skills and technical efficiency across eight industry subsectors.

Based on the evidence that there is a positive relationship between human capital and productivity efficiency, this research aims to verify the existence concerning Senegalese companies of a causal relationship between human capital and productivity.

3. Methodology

In the context of inefficiency, we use the stochastic production boundary model of BATTESE & COELLI (1995) as a reference framework. The latter has sought to build more reliable estimators of individual inefficiencies. According to these authors, we define two equations:

- a first equation relating to the stochastic production boundary;
- and a second that is a model of technical inefficiency. This model expresses the average of the technical inefficiency effects μ_i. These two equations are as follows:

$$\Pr od = F(X_i, \beta)\exp(v_i - \mu_i)$$

$$\mu_i = z_i\delta$$

with

- $Prod_i$, is the average productivity of the i^{th} company in the sample (i = 1, 2, ..., n); X_i is a vector (1xk) of the inputs used by the i^{th} company;
- $X = khboss, khstaff, I_{Matériels}, I_{Fixe}, I_{NTCI},$

  $\beta = \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6,$
- β is a vector (kx1) of the parameters to be estimated;

- the terms μ_i represent the effects of technical inefficiency and are assumed to be independent and distributed according to a normal distribution truncated to zero with an average μ_i and a variance σ_u^2 ($N(\mu_i, \sigma_u^2)$);
- The random error terms are represented by v_i. and are assumed to be independent and identically distributed according to $N(0, \sigma^2)$;
- z_i is a vector of company-specific variables that is supposed to influence their technical efficiency;
- δ is a vector (mx1) of unknown parameters to be estimated.
- μ measures the difference between the observed output Prod and the maximum output achievable by the efficient technology. It represents technical inefficiency and is nil for technically efficient companies or decision-making units located on the border ($\mu \geq 0$).
- v a random term that captures random shocks ($-\infty \leq v \leq +\infty$)

The technical efficiency index of the i^{th} company is given by:

$$TE_i = \exp(-\mu_i) = \frac{\mathbf{Prod}}{F(X_i, \beta)\exp(v_i)}$$

With $Prod_i$ being the observed level of productivity and $F(X_i, \beta)$ $\exp(v_i)$ being the stochastic production frontier.

We consider a production function of the COBB-DOUGLAS type, because it is more appropriate for the representation of our data. It is established in the following form:

$$\ln \mathbf{Prod}_i = \beta_0 + \sum \beta_k \ln X_{ki} + \nu_i - \mu_i$$

$$\mu_i = \delta_0 + \sum \delta_k z_{ki}$$

The table 1 gives a description of our variables:

Based on the information in the table 1, the production function to be estimated is therefore as follows:

$$\ln Prod_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \ln X_{6i} + v_i - \mu_i$$

$$\mu_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{2i} + \delta_3 z_{3i}$$

We estimate the parameters β_k of the stochastic model and those of the technical inefficiency model (δ_k), using the maximum likelihood method using the Frontier program version 4.1 (See COELLI, 1994). It is a program that estimates the variance parameters of the likelihood function in terms of $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / \sigma^2$. We determine whether the production boundary is deterministic or stochastic from the hypothesis test on the parameter γ. If H0: $\gamma = 0$ is rejected, then there is a stochastic production boundary. In this case, the previous method must be applied. However, the OLS method will be applied if the production boundary is deterministic.

Concerning the technical inefficiency model, it can only be estimated if the technical inefficiency effects μ_i are stochastic and have particular distributional properties (BATTESE & COELLI, 1995). To do this, we will test the following hypotheses:

- the effects of technical inefficiency are not stochastic, H0: $\gamma = 0$; under this assumption, the stochastic boundary model is reduced to a traditional function where the explanatory variables of the technical inefficiency model are also included in the production function;
- the effects of technical inefficiency are not present, H0: : $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$;

We use the following likelihood function to test all these:

$\lambda = -2\{\ln[L(H0)] - \ln[L(H1)]\}$, where L(H0) and L(H0) respectively represent the values of the likelihood functions under the null hypothesis, H0, and the alternative hypothesis, H1: $\gamma > 0$.

If the null hypothesis, H0, is true, λ approximately follows a Chi-square distribution whose degree of freedom is equal to the number of restrictions imposed or a Chi-square distribution and γ = 0 (COELLI, 1995).

4. Presentation of data and descriptive statistics

The data we used to measure efficiency in terms of the use of resources used are taken from the World Bank's Senegalese business survey database. For some time now, the World Bank has been conducting a series of surveys[1] on topics such as the business environment, access to finance, the state of corruption, infrastructure, crime, competition, productivity measurement, the state of technological innovation, the skill level of the workforce, trade, business in emerging and developing countries. It is in this context that this institution conducted this survey in Senegal. The survey is based on panel data collected from the companies surveyed, mainly in 2003 and 2007. The table 2 specifies the structure of the panel for this survey.

The targeted schools cover the regions of Dakar, Kaolack, Thiès and Saint-Louis. The choice of these regions is due to the fact that they are the main regions of Senegal in terms of economic dynamism and where the industrial fabric is the most important. Out of the 887 companies, we were able to construct our sample of 305 companies, including 259 traditional companies and 46 modern companies, because a lot of data was missing in the database corresponding to response refusals or input errors.

The production units considered for the purposes of this paper are companies in traditional and modern sectors. According to the definition of this World Bank survey, traditional companies are made up of manufacturing, food, textile, clothing, metal, mining and construction industries. These traditional companies use similar technologies in their production function and there are

[1] For the presentation of these surveys see www.enterprisesurveys.org/methodology.

259 of them. The same is true for modern companies that consist of establishments in chemicals, plastics and rubber products, machinery and equipment, electronics and information and communication technologies.

The descriptive statistics of the main variables are grouped in the tables 3 and 4 according to sectors modern and traditional, respectively.

For modern companies, the average values of technology expenditure and productivity are respectively in the order of 1.910^7 and 1.4310^7 F CFA, 210^7 and 1.0910^9 F CFA. For the technology expenditures of modern enterprises, the minimum and maximum values are 610^4 and 1.010^8 F CFA respectively. Standard deviations are high. This shows a greater dispersion of expenditures around the average value.

Human capital corresponds to the number of years of education obtained, while experience is related to the number of years of seniority of the head of the company.

The average level of human capital of the employee is three years' schooling, while the average level of education of the entrepreneur is 13 years.

In traditional companies, the average values of transport expenditure and fixed investments are respectively 1.8710^7 and 6.3810^7 F CFA. These two types of expenditure have a minimum value of 0 and a maximum value of between 2.510^9 and 4.6410^9 F CFA respectively. For these expenditures, standard deviations are high. This shows a greater dispersion of observations around the mean value.

The minimum and maximum values of the entrepreneur's experience are 1 and 55 respectively, while the average value is 16 years.

The maximum level of education of the entrepreneur is 17 years, while the average level of the employee's maximum human capital is 15 years.

There are never surveys in 2014[2]. That Enterprise Survey is a firm-level survey of a representative sample of an economy's private sector. The surveys cover a broad range of business environment topics including access to finance, corruption, infrastructure, crime, competition, and performance measures. In this paper, we have chosen to study the productive efficiency of Senegalese companies, a source of economic growth and development. The objective is to assess their efficiency based of the control variables that characterize them. Such variables include transport expenditure, fixed investment, technology expenditure, company experience, company manager's level of education, and employee's level of human capital. In the 2014 survey, the human capital variables of the manager and the average employee are not available. They constitute the most important variables of our study. This is why, we did not use the most recent survey, that of 2014. Only the surveys of 2003 and 2007 allow us to assess the efficiency of capital on the productivity of businesses. Senegalese based on available data. Identical processing is impossible. But between 2007 and 2014, we can look at two indicators the proportion of workers offered formal training and proportion of skilled workers (out of all production workers), which can give an idea of the evolution of capital in manufacturing firms.

Between 2007 and 2014 (table 5), we saw an increase in the Proportion of workers offered formal training, which went from 52% to 61.4%. On the other hand, the Proportion of skilled workers (out of all production workers) decreased from 73.6 to 69% in all manufacturing. For example, for the food sector we also note a decrease in this last indicator between 2007 (76.6%) and 2014 (64.7%).

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[2] For the presentation of these surveys see
https://www.enterprisesurveys.org/en/data/exploreeconomies/2014/senegal

5. The stochastic production frontier model: empirical results

The estimation of the statistical boundary model by the "Frontier" program version 4.1 under STATA 11 gives the following results in modern and traditional companies.

5.1. Evidence for Senegalese modern enterprises

In each type of sector, we assume that the production units or companies have the same production technologies. With the chosen orientation (variable scale returns), we present the results of the application of the stochastic production frontier model in modern enterprises in Senegal (Table 6).

We notice that the value γ (0.50) is greater than 0 and significantly different. This result allows us to reject the hypothesis that the variance of efficiency is null. This justifies the existence of a stochastic border. Therefore, the integration of the inefficiency term into the random term is justified. The OLS method is not adapted to our data.

The table shows the existence of technical inefficiency effects that are stochastic as well, according to the value of γ (0.50) which is different from (0), hence the rejection of the two hypotheses.

The estimated coefficients correspond to the elasticities. They are all positive except for transport investment (-0.21). This means that the variables level of education and experience of the company manager, the average level of education of the employee, spending on technology and fixed investment have a positive influence on the level of productivity of companies. Indeed, for example, a 10% increase in the manager's level of education leads to a 7.3% increase in productivity in modern companies in Senegal. Only the effects of the variable's investments in technologies and total fixed investments are significant at the 1 and 10% thresholds respectively.

5.2. Evidence for Senegalese traditional companies

We present the results of the application of the stochastic production frontier model in traditional Senegalese firms (Table 7).

When reading the table, we see the value γ (0.75) is higher and significantly different from zero. This result rejects the hypothesis that the variance of efficiency is null. So there is a stochastic border. Therefore, the integration of the inefficiency term into the random term is justified, so the OLS method is not adapted to our data.

The first important result that emerges from the table concerns the test on the existence or not of technical inefficiency effects. The technical inefficiency effects are stochastic; similarly, their absence is rejected, according to the value of γ (0.75), hence the rejection of the two hypotheses (no existence of technical inefficiency effects and inefficiency effects are not stochastic).

The estimated coefficients are all positive. This means that the variables of the manager's level of education, his experience, the average level of education of the employee, the expenditure on technologies in equipment and the fixed investment in them have a positive influence on the level of productivity of companies. Indeed, for example, a 1% increase in spending on new technologies and communication leads to a 0.84% increase in productivity in traditional companies. The effects of investments in transport and the employee's level of education are significant at the 1 and 10% thresholds respectively.

After BATTESE & COELLI (1995), we present the technique of estimating the stochastic border of AIGNER et al. (1977), in order to compare the results. The function of production to be estimated with AIGNER et al. (1977) is:

$$\ln \Pr od_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_5 \ln X_{6i} + (v_i + \mu_i)$$

AIGNER, LOVELL and SCHMIDT (1977) derived the likelihood function of the model based upon two parameters σ^2=

$\sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u / \sigma_v$ ($0 \leq \lambda \leq \infty$). BATTESE & COELLI (1995) replaced λ with $\gamma = \sigma_u^2 / \sigma^2$ ($0 \leq \gamma \leq 1$).

In Tables 8 and 9, we simply compare the results of the stochastic estimation with the method of BATTESE & COELLI (1995) to those of the method of AIGNER et al. (1977), respectively in modern and traditional businesses.

In modern companies, the estimation of the stochastic production function with AIGNER & al. (1977) gives coefficients of the different variables which are all positive (table 8). These results confirm the conclusions we obtained with BATTESE & COELLI (1995). The only difference lies in the Investment in transport equipment variable. With AIGNER & al. (1977), the coefficient is 0.14, while it is -0.21 with BATTESE & COELLI (1995).

In traditional firms (table 9), all the coefficients are positive using the two methods (those of AIGNER & al. (1977) and BATTESE & COELLI (1995)). For these two methods, the results are consistent with regard to the effect of the explanatory variables on the level of productivity in these firms.

5.3. Discussion of the Results of the stochastic production frontier model

In view of our results, the human capital represented by the level of education of the manager and the average level of human capital of the employee has a positive impact on productivity in traditional and modern companies. This result corroborates those found in the literature such as the study by DANQUAH & OUATTARA (2014) on a panel of Sub-Saharan African (SSA) countries between 1960 and 2003, after decomposing total factor productivity into its main components. Their results show that the effect of human capital on efficiency change is positive and statistically significant; whilst its effect on technical change is statistically insignificant. LOCKEED & al (1980) on data from a number of developing countries had already

found that four years of elementary education increases a farmer's productivity by an average of 8.7%. However, there is some evidence to the contrary. For example, GURGAND (1993) econometric studies on Côte d'Ivoire indicate that more education does not improve farmers' productive efficiency and productivity, as MOOK (1981) and HOPCRAFT (cited by GURGAND) have already found. Other examples are the studies by BERG (1970) and BERY (1980) on industry and services in industrialized countries. They could not clearly demonstrate a significant positive relationship between education and productivity for tasks requiring higher levels of training. Contrary to the study by BUXON (1977), LAYARD & al. (1971) found that there was no significant positive relationship between the educational level of workers and average productivity in electrical engineering firms in the United Kingdom. This study carried out on eleven British industries and covering a period of five years, consisted of adjusting a COOB-DOUGLAS production function distinguishing highly skilled work (scientists and engineers) from the rest. Its results indicate that above a threshold, highly skilled labour productivity has a positive impact on labour productivity and that this impact increases over time.

Our findings reveal that firms in Senegal can also benefit from worker training as their productivity increases. This view parallels that of human capital theorists who believe that training improves the productivity of the individual. The spectacular level of economic development achieved by Japan and the newly industrialized countries in recent decades illustrates the importance of human capital in economic growth and therefore in the sphere of production. Authors like JAMISON Dean T. & MOOCK PETER R. (1984) found in a study conducted in ruralparts of Nepal that education increases the efficiency and therefore the individual productivity of farmers. These results confirm our conclusions. As for LOCKEED & al. (1987) in a work carried out on data from households in Bangladesh, they conclude

that education increases the productivity of rice, stimulates their production potential and reduces the inefficiency of farmers. This educational effort is facilitated by access to new production techniques, unlike in Africa and Latin America where agricultural production remains partly dominated by traditional tools.

BLACK & LUNCH (1996) use the production function of COBB-DOUGLAS to analyze the effects of various aspects of human capital and training on labor productivity. They found that labor productivity is higher in firms that employ highly educated workers. A study by LUNDVALL & BATTESSE (2000) found mixed effects in all sectors compared to the work carried out by SORDERBOM and TEAL (2003) which found minor effects of human capital on labor productivity. In contrast to these authors and our conclusions, a study by GOEDHUYS & al. (2006) found no impact of human capital indicators on labor productivity in Tanzania's manufacturing enterprises except for the level of education of the head of the enterprise whose impact on productivity is positive. This result in Tanzania was confirmed by NIRINGIVE, Indeed, his study on manufacturing companies in some countries of sub-Saharan Africa (Uganda, Tanzania, and Kenya). He tested the impact of human capital on labor productivity using the generalized least squares method. The results indicate that the proportion of skilled workers and the level of education in Uganda, training, the proportion of skilled workers, the level of education of the business manager in Tanzania, the training and the average level of education in Kenya are positively linked to labor productivity.

At the level of sub-Saharan Africa, we can retain some works which support our conclusions. Indeed, LUVANDA & al. (2010) show that the quality of human capital has a positive effect on labor productivity in manufacturing firms in East Africa. However, authors like BATTESE & LUNDVALL (2000) find that this effect of human capital on productivity varies from one sector to another. The same could be said of DANNON (2009), who

measures the productivity of banks in the WAEMU. According to the results of this author, aggregate factor productivity of WAEMU banks experienced a positive development between 1996 and 2006. Finally, BINAM & al. (2006) show that weak education affects total productivity factors in Sub-Saharan African countries.

6. The inefficiency model: empirical results

We present the results of the inefficiency model in traditional and modern senegalese firms.

6.1. Evidence for modern enterprises in Senegal

The table 10 summarizes the effects of specific variables on the productive inefficiency of Senegalese firms. We note that the specific small and medium size of the company, the informal aspect and the fact that the investments are of domestic or foreign origin explain the productive efficiency of these establishments, because their inefficiency coefficients are negative. This implies that their efficiency coefficients are positive. The coefficient of the size variable is significant at the 1% threshold.

On the other hand, we find inefficiency coefficients greater than zero for variables describing the large or small size of the firm, the formal nature and the ownership of capital by a partnership. The size coefficient tells us that if the company increases in size, the return is decreasing. Similarly, the origin of investments through a partnership leads to productive inefficiency of the company.

6.2. Evidence for traditional enterprises in Senegal

The table 11 summarizes the results of the inefficiency model. These results relate to the effects of specific variables on the productive inefficiency of Senegalese firms. We note that for the specificities of small and large sizes, the formal nature and the fact that the investments are of partnership origin explain the productive efficiency of traditional companies, because their inefficiency coefficients are negative. This implies that their efficiency coefficients are positive. The coefficients of the small

and medium size variables are significant at the 5% and 10% thresholds respectively.

On the other hand, we find inefficiency coefficients greater than zero for medium size specificities, informality and capital ownership by both a national and a foreigner. The average character makes the company inefficient to produce. Similarly, the informal nature and national and foreign origin of investments lead to productive inefficiency of the company in the traditional sector.

6.3. Discussion of the Results of the inefficiency model

Depending on the type of ownership, we have domestic-owned, foreign-owned and partnered firms. Our results have shown that in the modern sector, a company is efficient, when it is small or medium sized, formal and when its capital is 100% owned either by a national or by a foreigner. In the traditional sector, the business should be small or large, formal, and its capital must be partnership based for it to be efficient. The relationship between form of ownership and business efficiency has produced mixed results in the economic literature. Indeed, some empirical studies have shown that private companies are more efficient than national companies are. This is the cases of the work of BAGDADIOGLU & al. (1996) on public and private distribution companies in Sweden (1970-1990) and KUMBHAKAR & HJALMARSSON (1998) on two hundred and eighty-nine Swedish distributors (1970-1986). These results are consistent with our findings when the capital of the business is 100% owned by a (private) foreigner. On the other hand, other studies invalidate the supremacy of the private enterprise compared to the enterprise of public property. Indeed BHATTACHARYYA & al. (1995), on public and private sector organizations in the United States have shown that public companiesare more efficient than private companies, especially when they are large. HAUSSMAN & NEUFELD (1991) reached the same conclusion in their study of sixty-four state-owned and four private distribution companies in

Turkey. The results of BHATTACHARYYA & al. (1995 and HAUSSMAN & NEUFELD (1991) are in line with our conclusions on the efficiency of companies whose capital is 100% owned by the national. Likewise, in a study of thirty public and one hundred and twenty-three private firms in the United States, FÄRE & al. (1985) showed that public companies rank better than private companies in terms of technical efficiency. The same is true for HJALMARSSON & VEIDERPASS (1992) out of two one hundred and eighteen private enterprises and ninety-seven municipalities in the United States (1897-1998). National and municipal enterprises are often more efficient, however CUBIN & al. (1987) in 317 local communities in England and Wales (1984-1985). The technical efficiency of private companies is higher than that of public companies. Contrary to our conclusions in the context of modern companies, partnership character is more efficient. EHRLICH & al. (1994) support the same conclusion. In fact, according to these authors, the change in status from "public" to "private" increases the productivity rate in the long term.

The following studies put the relationship between the type of business ownership and productive efficiency. Some corroborate with our results. Others come to contradict them. Indeed, the study by YAO & ZHANG (2001) on technical efficiency for 37769 Chinese companies confirms this contradiction. These authors compare, on the one hand, private and public ccompanies and, on the other hand, large and small firms. They also considered the impact of foreign direct investment, research and development and the geographic location. The results show that private companies are more efficient than public companies, that small companies are just as efficient as large firms up to a certain size. They conclude that the type of ownership, the size of firms, foreign direct investment are important determinants of technical efficiency. DRIFFIELD & MUNDAY (2001) studied the technical efficiency of manufacturing industries in Great Britain and the role played by

foreign direct investment As a result of their use of stochastic production boundaries, they find a positive relationship between foreign direct investment and the level of efficiency. The studies of RAO & TANG (2000), DOUGHHERTY & MC GUCKIN (2002) reach mixed conclusions. RAO & TANG (2000) analyzed the performance of Canadian-controlled and foreign-controlled manufacturing firms in terms of productivity. Estimates indicate that Canadian-controlled firms are on average 19/100 less productive than their foreign-controlled rivals are.

DOUGHHERTY & MC GUCKIN (2002) investigated the effects of privatization and decentralization on efficiency in 20,992 large and medium-sized Chinese enterprises. They find that privatization has a positive effect on efficiency. TOUFIK (2002) used the parametric approach to estimate the efficient techniques of Moroccan and foreign companies. He finds that foreign companies have higher levels of technical efficiency than Moroccan companies. This performance within the manufacturing industry is explained by the structure and the behavior of foreign companies within the manufacturing industries in Morocco. Foreign firms, have advanced technologies, pay very high wages rewarding employees, use the best manufacturing processes and management and quality control techniques. This is what explains this superiority in terms of efficiency.

Our study also linked company size to efficiency. The results obtained agree with the conclusions of WILLIAMSON (1967). Indeed, this author was one of the first to establish a link between company size and efficiency. Using a model, he shows that the loss of managerial efficiency in large hierarchical firms limits the optimal firm size. DHAWAN (2001) estimates that small businesses are more open to innovation and able to innovate, in part thanks to a more flexible organizational structure and the fact that their managers are more inclined to take risks. That said the bulk of the empirical results. In contrast, in the OECD (Organization for Economic Cooperation and Development, 2008)

survey, it is common to observe that labour productivity in advanced economies is, on average, higher in large firms and plants than in small ones.

7. Conclusion

Using the World Bank's "business surveys", conducted between 2003 and 2007, in a representative sample of traditional and modern Senegalese companies, we studied productive economic efficiency in terms of inputs specified with the stochastic border approach inspired by BATTESE & COELLI (1995). The results showed that the level of education and experience of the company manager, the average level of education of the employee, the expenditure on technologies equipment and the fixed investment in them have a positive influence on the level of productive efficiency of companies in both the traditional and modern sectors. The effect of transport expenditure on productivity is positive in modern firms, while it is negative in traditional firms.

In addition, we tested the effects of specific variables such as size (small, medium or large), status (formal or informal) and origin of capital (domestic, foreign or partnership) on firm efficiency. The characteristics such as large size and partnership have a negative effect on the efficiency of modern firms, as well as that of informal, medium size, foreign and domestic origins of traditional enterprises. Only the effects of the specificities of small size and formality are positive in both modern and traditional companies.

Based on this result, we recommend that Senegalese companies favour a qualified workforce in their personnel recruitment policies. The latter should be trained in new processes and techniques to be able to participate fully in the company's production. Based on our conclusions, the company should be managed by an executive with a level of education and proven experience to increase production and productive efficiency. It

should invest more in the training of its staff, be formal and have a private status for greater productive efficiency.

In the modern sector for the company to be efficient, it should be small or medium sized, formal and its capital must be 100% owned either by a national or a foreigner. In the traditional sector, the company should be small or large, formal and its capital must come from a partnership to be efficient.

Taking all these elements into account, the management of companies can achieve gain in productive efficiency, and therefore greater productive efficiency. This could increase their production and consequently economic growth on a global scale.

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Appendix

Table 1: Description of outputs, inputs and variables specific to companies

Variables of the stochastic boundary	Description
The output (Prod)	Average productivity
The level of education of the leader X_1	Number of years of education of the leader
The average level of education of the employee X_2	Number of years of education of the average employee
INTCI (X_3)	Investment in ICTs
IM Hardware (X_4)	Investment in transport equipment
IFix (X_5)	Expenditure in buildings land
Experience of the company manager (X_6)	Experience of the manager or business leader
Company specific variables	Description

Company size z_1	The size can be small (z_{11}), large (z_{12}) or medium (z_{13})
The capital of the company z_2	The capital can be held by a national (z_{21}), a foreigner (z_{22}) or a partnership (z_{23})
The character of the company z_3	The company is formal (z_{31}) or informal (z_{32})

Source: Calculations by the author based on data from World Bank business surveys in Senegal.

Table 2: Panel of surveyed companies in Senegal in 2003 and 2007

Years	**Number of companies surveyed**
2003	188
2007	526
2003 and 2007	148
Other years	25
Total	887

Source: Data from World Bank "business surveys" in Senegal

Table 3: Descriptive statistics of the variables

Variables	**Obs.**	**Average**	**Standard deviation**	**Min Max**
Transportation expenditures	46	2.1010^{8}	6.7210^{8}	0 3.010^{9}
Fixed investments	46	2.9310^{8}	5.3810^{8}	0 1.910^{9}
Technology spending	46	9.7107	2.10107	610^{4} 1.010^{8}
Average human capital of the employee	46	3	4.06	0 15
Human capital of the company manager	46	13	4.25	0 17
Experience of the company manager	46	13	12	2 52
Productivity	46	1.4310^{7}	1.64107	1.0810^{6} 7.51107

Source: Calculations made by the author based on data from World Bank business surveys in Senegal.

Table 4: Descriptive statistics of traditional enterprises

Variables	**Obs.**	**Average**	**Standard deviation**	**Min Max**

Transportation expenditures	259	1.871 0^{7}	1.6710^{8}	0 2.510^{9}
Fixed investments	259	6.381 0^{7}	3.6610^{8}	0 $4.64\ 10^{9}$
Technology spending	259	6.901 0^{7}	5.1210^{7}	0 7.9310^{8}
Average human capital of the employee	259	4	3.16	0 15
Human capital of the company manager	259	8	5.28	0 17
Experience of the company manager	259	16	9.43	1 55
Productivity	259	8.821 0^{7}	1.8910^{7}	210^{5} 210^{8}

Source: Calculations made by the author based on data from World Bank business surveys in Senegal.

Table 5: Proportion of workers offered formal training and Proportion of skilled workers (out of all production workers) between 2007 and 2014

Year	Subgroup	Top Subgroup Level	Subgroup Level	Proportion of workers offered formal training (%)*	Proportion of skilled workers (out of all production workers) (%)*
2007	Sector	Manufacturing	All	52	73.6
2007	Sector	Manufacturing	Food	56.7	76.4
2007	Sector	Manufacturing	Garments	35.9	73.7
2007	Sector	Manufacturing	Chemicals & Chemical Products	n.a.	55.9
2007	Sector	Manufacturing	Fabricated Metal Products	n.a.	75.8

2007	Sector	Manufacturing	Rest of Universe-Manufacturing	60.6	73.5
2014	Sector	Manufacturing	All	61.4	69.1
2014	Sector	Manufacturing	Food	60.7	64.7
2014	Sector	Manufacturing	Other Manufacturing	62	74.4

Source :
https://www.enterprisesurveys.org/en/data/exploreeconomies/2014/senegal

Table 6: Results obtained by the stochastic production boundary model in modern enterprises in Senegal

Variables	The coefficients	The stand. Error
Constant	11.67	3.02
Ln X_1	0.73	0.91
Ln X_2	0.02	0.50

Ln X_3	0.16***	0.41
Ln X_4	-0.21	0.35
Ln X_5	0.41*	0.22
Ln X_6	0.08***	0.57
σ_v	0.61	0.13
σ_μ	0.01	2.38
σ^2	0.37	0.17
	0.50	2.41

***p<1%.** p<5%. *p<10%

Log likelihood-ratio test of sigma_=0:
chibar2(01)=0.00 Prob>chibar2=1.0

Source: Calculations by the author based on data from World Bank surveys in Senegal.

Table 7: Results obtained by the stochastic production boundary in traditional enterprises in Senegal

Variables	The coefficients	The stand. Error
Constant	6.69***	1.89
Ln X_1	0.26	0.4
Ln X_2	0.54*	0.28
Ln X_3	0.84	0.10
Ln X_4	0.47***	0.13
Ln X_5	0.09	0.08
Ln X_6	0.37***	0.19
σ_v	0.89	0.08
σ_μ	0.04	2.08
σ^2	0.79	0.17
	0.75	2.11

***p<1%.** p<5%.
*p<10%

Log likelihood-ratio test of sigma_=0: chibar2(01)=0.00	Prob>chibar2=1.0

Source: Calculations by the author based on data from World Bank surveys in Senegal.

Table 8: Comparison of the estimation results with the method of BATTESE and COELLI (1995) and that of AIGNER et al. (1977) in modern enterprises in Senegal

Variables	The coefficients with BATTESE and COELLI (1995)	The coefficients with AIGNER et al. (1977)
Constant	11.67 (3.02)	1.26
Ln X_1	0.73 (0.91)	0.12 (2.35)
Ln X_2	0.02 (0.50)	0.29 (5.16)
Ln X_3	0.16*** (0.41)	0.25 (4.96)
Ln X_4	-0.21 (0.35)	0.14 (5.42)
Ln X_5	0.41* (0.22)	0.06 (6.45)
Ln X_6	0.08***(0.57)	0.18 (9.64)

σ_v	0.61 (0.13)	0.52 (3.46)
σ_μ	0.01 (2.38)	0.08 (1.74)
σ^2	0.37 (0.17)	0.03 (2.69)
		0.27 (1.06)
	0.50 (2.41)	

***p<1%.** p<5%.
*p<10%

Log likelihood-ratio test
of sigma_=0:
chibar2(01)=0.00 Prob>chibar2=1.0

Source: Calculations by the author based on data from World Bank surveys in Senegal.

Table 9: Comparison of the estimation results with the method of BATTESE and COELLI (1995) and that of AIGNER et al. (1977) in traditional enterprises in Senegal

Variables	The coefficients with BATTESE and COELLI (1995)	The coefficients with AIGNER et al. (1977)
Constant	6.69*** (1.89)	5.34
Ln X_1	0.26 (0.4)	0.27 (6.13)
Ln X_2	0.54* (0.28)	1.35 (4.25)
Ln X_3	0.84 (0.10)	0.02 (1.36)
Ln X_4	0.47*** (0.13)	0.01 (6.55)
Ln X_5	0.09	0.61 (2.39)
Ln X_6	0.37***	0.18 (9.64)
σ_v	0.89 (0.08)	0.17 (7.62)
σ_μ	0.04 (2.08)	0.58 (5.98)
σ^2	0.79 (0.17)	0.26 (3.50)
		0.04 (4.72)
	0.75 (2.11)	

***p<1%.** p<5%. *p<10%		
Log likelihood-ratio test of sigma_=0: chibar2(01)=0.00	Prob>chibar2=1.0	

Table 10: Results of the inefficiency model in modern enterprises in Senegal

The stochastic boundary model	The parameters	The coefficients	The stand. Error
Constant	δ_0	1.59***	0.15
Z_{11}	δ_{11}	-0.02***	0.23
Z_{12}	δ_{12}	0.08***	0.19
Z_{13}	δ_{13}	-0.04	0.11
Z_{21}	δ_{21}	-0.01	0.01

Z_{22}	δ_{22}	-0.01	0.02
Z_{23}	δ_{23}	0.03	0.11
Z_{31}	δ_{31}	0.02	0.074
Z_{32}	δ_{32}	-002	0.074

*** p<0.01, ** p<0.05, * p<0.1

Source: Calculations by the author based on data from World Bank business surveys in Senegal.

Table 11: Results of the inefficiency model in traditional enterprises in Senegal

The stochastic boundary model	The parameters	The coefficients	The stand. Error
Constant	δ_0	0.96	0.008
Z_{11}	δ_{11}	-0.053**	0.24
Z_{12}	δ_{12}	-0.01	0.003
Z_{13}	δ_{13}	0.057*	0.27
Z_{21}	δ_{21}	0.001***	0.007

Z_{22}	δ_{22}	0.001	0.0072
Z_{23}	δ_{23}	-0.0019***	0.006
Z_{31}	δ_{31}	-1.22	0.012
Z_{32}	δ_{32}	1.22	0.023

***p<1%,** p<5%, *p<10%
Source: Calculations by the author based on data from World Bank business surveys in Senegal.