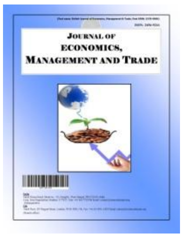

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Direct and Indirect Macroeconomic Effects of Malaria in Senegal

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Malaria constitutes, beyond a public health problem, a major challenge for the development of endemic countries. The objective of this study is to estimate the economic cost of malaria in Senegal. A logarithmic double model with interaction effect is used and estimated, using a time series data from 1995 to 2019, by Ordinary Least Squares (OLS) method. At the macroeconomic level, when malaria morbidity increases by 1%, GDP per capita falls by 0.00467. Applied to total GDP, this corresponds to an average annual loss of US $ 108 million. In addition, the study shows a decrease of the labour factor impact when taking into account the interaction effect of malaria. In fact, in the case of a 1% increase in malaria, the contribution resulting from a 1% increase in the labour force decreases by 0.48 point. Such consequences due to malaria can lead in the long run to adverse effects on economic growth and on efforts to fight poverty in Senegal.

Keywords: Economic cost; malaria; logarithmic double model; interaction effect.

JEL Classification: I12, I18, C22.

1. INTRODUCTION

Malaria is an infectious parasitic disease that is a major public health problem. According to the World Health Organisation (WHO) and the World Bank (WB), malaria is a preventable and curable disease. However, it is one of the most common and devastating diseases. Malaria cases are

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most prevalent in tropical and subtropical regions of the world, a disproportionate share of which are in the African continent.

WHO (2014) estimates that 1.2 billion people are at high risk of contracting malaria during the year and between 124 and 283 million malaria cases are identified leading to an average of 584,000 deaths. The burden of malaria is greatest among children under 5 years of age and pregnant women, who are the most vulnerable group to the disease. They account for 90% of all deaths, of which 78% are in the under-five age group (WHO, 2014).

In Senegal, malaria has long been a major public health problem, as evidenced by the establishment of the National Malaria Control Programme "PNLP"[1] in 1995. According to the PNLP [1], there are two zones with different levels of endemicity in Senegal: the northern zone with low malaria endemicity and the rest of the country where endemicity is higher. However, although the country is characterised by a rather stable endemicity with peaks during the rainy season, malaria remains one of the main factors of morbidity and mortality. In 2019, 354,708 confirmed malaria cases were recorded (leading to 260 deaths, of which 65% of these were children under five (05) [1]. The actions to fight the elimination of this disease have for the most part focused on vulnerable groups and have produced very promising results. Indeed, between 2018 and 2019, there was a decline in the incidence from 33.9% to 21.9% [1] and the mortality rate due to malaria fell by 61%.

Beyond its heavy impact on human health, the disease requires the mobilisation of financial resources at the national and international level in order to face the persistence of the disease. It is in this context that it is considered economically costly [2]. Economic cost refers, according to McCarthy et al. [3], to a monetary value of the disease and its impact on the economy. WHO (2014) estimates that the funds devoted to malaria, in 2013, are at US$ 2.6 billion with almost 18% of these resources made up of national funds the most affected continent in the world, Africa, alone absorbs the 72% of resources. Despite all the resources that have been deployed, malaria still causes a significant shortfall in endemic countries. The disease requires households to spend their income on malaria prevention and treatment. In these countries, these expenses are not trivial for the population [4]. Indeed, it is estimated that in sub-Saharan Africa, according to the Abuja Declaration (2001), these expenses can represent more than 25% of household income. Thus, malaria has a detrimental impact on the socio-economic level of countries. Indeed, it is estimated that in Sub-Saharan Africa (SSA) the economic loss due to the disease amounts to US$ 12 billion per year (WHO, 2010). In addition, malaria can also affect the productivity of workers and thus the level of national production [2,5]. As a result, malaria is becoming not only a public health problem, but also an economic development problem [6].

In view of the above, the objective of this paper is to highlight the economic impact of malaria in Senegal. More specifically, it will assess the effect of malaria morbidity on GDP per capita and then analyse the impact on labour productivity. In Senegalese context, previous research on malaria are focus on medical aspects and on the impact of impregnated mosquito net (ITN) distribution [7-9]. This study contributes to malaria research in Senegal by providing evidence on the impact of malaria from an economic perspective. Beyond the knowledge gap to be filled, the contribution of this paper is to analyse the effects of malaria through indirect effects on labour productivity. In the rest of the document, we will present the malaria situation, then review the literature before presenting the methodology and finally the results.

2. LITERATURE REVIEW

For a long time, macroeconomic models ignored the importance that health could have on the wealth accumulation process for countries. It was only later that health was considered as a source of consumption but also of investment. These aspects, investment and consumption, stem from the fact that health is a capital stock and an economic asset.

Health is a major economic asset, a means of survival for poor population groups [10]. An endemic disease such as malaria can discourage foreign investment and therefore diverts considerable resources away from productive investment. Thus, foreign investors will become less attracted to a country with high malaria endemicity that affects more children, the future workforce, and will also have less incentive to

[1] PNLP referrer to « Programme National de lutte contre le Paludisme »in french

train the population whose life expectancy, especially working life, is greatly affected [11].

Several studies have sought to analyse the macroeconomic effect of malaria. Sub-Saharan African (SSA) countries, which bear a heavy human burden due to malaria, have been the subject of several investigations to show the economic effects of malaria on growth and development.

McCarthy et al. [3] sought to identify factors that may determine differences in malaria morbidity between countries and to analyse the relationship between malaria and economic growth in a sample of 180 countries. Through a classification of countries, the study confirms that the climatic factor plays a major role in explaining differences in malaria intensity. A malaria exposure index defined as the product of the area affected by malaria and the percentage of malaria cases due to the most severe malaria vector that a population faces, is used to analyse the effect of malaria on growth. In fact, it is noted that for a quarter of the countries considered, this impact is above 25% per year for highly affected countries, particularly in SSA countries. Thus, according to these authors, malaria leads to a reduction in economic growth of 0.05% per year on average.

Gallup and Sachs [12] examine the relationship between malaria and growth by analysing the impact of the disease on countries' per capita income and poverty. They use the malaria prevalence index and the “malaria mortality intensity index” defined as the product of the fraction of the population at risk of malaria and the fraction of the number of malaria cases. The relationship between malaria and economic growth is verified through a cross-sectional regression over the period 1965-1990. Indeed, taking into account factors related to the initial level of income, the initial human capital stock of countries, economic policy through the degree of openness and the level of life expectancy among others, they show that countries with a high level of malaria in 1965 have a growth that decreases by 1.3% per year. Furthermore, they note that over the period 1956 to 1990, a 10% reduction in the malaria index corresponded to an increase in annual economic growth of about 0.3%.

Furthermore, the comparative analysis of income levels between malaria-affected and non-malaria-affected countries confirms the results of Gallup and Sachs [12]. In fact, GDP (PPP) in a malaria-free country is more than five times that of a malaria-endemic country, i.e. US$ 8268 versus US$ 1526 in 1995. Beyond this difference in income, the growth rates of the economies of malaria-endemic countries are lower, at 0.4% per year, compared to 2.3% per year for non-malaria-endemic countries, as shown in the earlier study by Gallup and Sachs [12].

Okorossobo et al. [6] looked at the economic cost of malaria in sub-Saharan Africa, particularly in six countries (Chad, Ghana, Mali, Nigeria, Rwanda and Uganda). In these countries, malaria has a negative impact on national production. Indeed, during the period under review, the loss of GDP attributable to malaria is very high for Nigeria and Chad, respectively 3.8% and 8.9%. While comparatively the loss due to malaria is relatively lower for Ghana and Rwanda, at 0.41% and 0.08% respectively. Thus, the studies conducted in the different countries reveal that malaria has a negative impact on real GDP growth and that, in general, real GDP growth declines with any increase in malaria morbidity.

Orem et al. [13] looked at the impact of malaria-related morbidity on GDP in Uganda. They use the production function approach of the economy to model the relationship between disease burden and GDP by OLS. Macroeconomic data from quarterly secondary sources between 1997-2003 were used to run the regression using a double log econometric model with interaction. The estimates indicate a negative sensitivity (elasticity) of GDP per capita to malaria of 0.175. They then use the Gujarati marginal effect calculation to determine the malaria burden. Thus, the authors show that a one-unit increase in malaria-related morbidity leads to a decrease in GDP per capita of US$ 0.00767 per year, holding other variables constant. This result applied to the total GDP for the year 2003 is a total loss of US$ 49.8 million or a loss of US$ 1.93 per capita for Uganda. In addition, the analysis of a possible effect of malaria on labour productivity, as captured by the economically active proportion, is carried out through an interactive process. Contrary to McCarthy [3], their estimate shows a decrease in the role of this factor in production, as the elasticity goes from 0.8373 to 0.5185 when malaria is modified.

3. METHODOLOGY

3.1 Basic Theoretical Approach

The analysis in relation to illness is based on Grossman's [14] consideration that health is a capital that depreciates. As health is a capital whose potential support is the individual, the deterioration of this state of health is individual before being generalised at the collective level. This aspect of individual capital to collective capital is because the health capital of a society or a nation is primarily the sum of the individual capitals that make it up [11]. Thus, in order to take into account the effect of illness in relation to the actions of agents, the utility function of populations, captured through a representative household, is designated by:

$$U= U(c, m) \tag{1}$$

This utility function is a function of the consumption of this household and its health status. This utility increases with consumption (C) and decreases under the effects of poor health (m), but at decreasing rates i.e $U_C > 0$, $U^2_C < 0$ and $Um < 0$, $U^2_m > 0$.

Consequently, if we look at the disease aspect, it emerges that it has a negative effect on the utility of households and therefore on their health capital, but in a decreasing manner. This decrease in the negative effect is because mortality due to illness is not taken into account, so the illness fades as time goes by. Considering that this representative household possesses the factors of production, the output is given by:

$$y = f (k, l, m, x) \tag{2}$$

With, $\frac{\partial f(k,l,m,x)}{\partial m} < 0$

The household's output (y) is a function of its fixed stock of capital (k), its level of labour, poor health (m) and other variables that may affect its output grouped in (x).

With the assumption [2] in the theory of a representative household, we can move on to country-level production. Indeed, production is assumed to be carried out with identical labour and capital endowments and with the same level of technological efficiency (Hertel and Reimer, 2010). The malaria variable in (2) is to be considered as the direct influence (or direct cost) of the disease on production. However, it is clear that these effects are accentuated by the consequences resulting from the interaction of the disease with other factors of production [5] which reflects the indirect effect (or indirect costs) of malaria on production. Indeed, the disease can affect labour productivity (L) or through its effects on capital productivity (K). Thus, equation (2) also has a general character allowing the effect of the disease on the factors of production to be taken into account.

[2] Assumption that allows for the transformation of inputs into the final product for a given level of technology (see Datta and Reimer (2013))

3.2 Empirical Model and Data

3.2.1 Empirical model

The production function (2) consists of an alternative writing of the Cobb Douglass production function ($AK^{\alpha}L^{\beta}$) with the addition of economic policy and health variables. Thus, the double logarithmic time series econometric model is given following a linearisation by:

$$\log\_pibt_t = a + \alpha_1 \log\_cap_t + \alpha_2 \log\_pea_t + \alpha_3 log\_palu_t + \alpha_4 \log\_educ_t + \alpha_5 \log\_depsante_t + \alpha_6 \log\_ouv_t + \alpha_7 \log\_palu - peat + \varepsilon t \tag{3}$$

In the context of the estimates, we will have the two following models:

Model 1:

$$\log\_pibt_t = a + \alpha_1 \log\_cap_t + \alpha_2 \log\_pea_t + \alpha_3 log\_palu_t + \alpha_4 \log\_educ_t + \alpha_5 \log\_depsante_t + \alpha_6 \log\_ouv_t + \varepsilon_t \tag{4}$$

Model 2:

$$\log\_pibt_t = a + \alpha_1 \log\_cap_t + \alpha_2 \log\_pea_t + \alpha_3 log\_palu_t + \alpha_4 \log\_educ_t + \alpha_5 \log\_depsante_t + \alpha_6 \log\_ouv_t + \alpha_7 \log\_palu - peat + \varepsilon t \tag{5}$$

With, pibt, cap, pea, palu, educ, depsante, ouv denoting in order: gross domestic product per capita, physical capital per capita, the share of the economically active population in the total population, malaria prevalence, education, health expenditure per capita and trade openness. The coefficients αi (*i=1, 2, 3, 4, 5, 6*) are interpreted as the elasticity of the dependent variable with respect to the corresponding independent variable. These coefficients give the percentage change in GDP associated with a change in the i^{th} explanatory variable. The specification of the model assumes that the level of malaria at time *t* affects the economy in that year. Given the specification with interaction, between malaria and pea, two specifications are needed. Indeed, a first specification without the interactive variable capturing the direct effects of the variables and a second one with the interactivity capturing the conditional effects is needed. The coefficients α_2 and α_3 to the coefficient to be taken into account with α_7 to take into account the interaction. The other coefficients not in the interactivity should not change. All variables are integrated of order 1, and then variables first differences (_d1) are used

Definition of some key variables:

- The Malaria Index: "***Palu***"

The malaria incidence factor is captured by a malaria index (expressed in per 100,000). It corresponds to the number of reported malaria cases in a year out of the total population. According to WHO (2013), the number of reported cases is considered to be the sum of confirmed malaria cases (confirmed by examination or Rapid Diagnostic Test (RDT)) and probable or unconfirmed malaria cases, i.e. cases that have not been tested but treated as malaria.

$$Palu = \frac{Number\ of\ reported\ cases}{Population} X\ 100.000$$

This specification assumes that the incidence of malaria is the same for all persons, thus without distinction of incidence by age. In previous studies on this topic, the definition varies according to the studies and the data considered. McCarthy et al. [3] consider the malaria index as the population exposed to malaria morbidity and having been treated.

- The interactive variable: "***log_palu_pea***"

This variable is specified by multiplying the variables malaria incidence and economically active population. It is used to capture, if it exists, the modification of the pea variable when the incidence of malaria is modified. Thus, the interactivity allows us to confirm or deny the presence of evolution conditional on the effect exerted by our variable of interest, the incidence of malaria.

log_palu_pea = log_palu*log_pea

Thus, this variable is constructed to show the impact of malaria on worker productivity.

3.2.2 Data

The study period, 1995-2018, is not an arbitrary choice. In addition to the continuous availability of most of the data from 1995 onwards, this year corresponds to the effective start of the malaria control programme (PNLP). The malaria data, the number of reported cases, are from the WHO database for 2019. Similarly, the health expenditure data is from this database. The World Bank's World Development Index (WDI) database for 2019 was used for data on the gross domestic product per capita ("pibt" variable), gross fixed capital formation, gross primary school enrolment ratio, the proportion of the economically active population in the total population, and exports and imports of goods and services.

As shown in Table 1 (descriptive statistics), the average level of per capita income over the period is US$738.08 or CFAF 310521.11425 with minimum wealth levels of $647.0676 and maximum wealth of $800.43. For the average level of investment per capita, this is US$170.05, or CFAF 71543.651. As for the share of the population available for production, it is on average 39.40% of the total population. With regard to the prevalence of malaria, which allows us to judge in relation to the incidence of malaria, the average level reached is 3268.91 per 100,000. However, it should be noted that the proportion of the population affected had a low of 127.679 (per 100,000) and a high of 11905.23 (per 100,000). In terms of primary education and health expenditure per capita, their average values are 74.86% and 24.19913% respectively over this period. In relation to the economic policy variable the share of trade in national production, it is on average 66.999% with a minimum share of 66.999% with a minimum share of over 50%.

3.3 Estimation Strategy

The model is presented in a double-logarithmic structure and the Ordinary Least Squares (OLS) method is used for econometric estimation purposes. The use of this estimation technique assumes that the explanatory variables are considered as the causes and the dependent variable as the effect [15]. In the specific context of our study, we were interested in the causal relationship between malaria and wealth level by considering the former as the cause and the latter capturing the effect. However, regression does not necessarily imply causality as it should be justified, or inferred, by theory pointing to observable facts that are empirically testable [15].

Table 1. Descriptive statistics

Variable	Mean	Std. deviation	Min	Max
pibt	738.09	56.08006	647.07	800.43
cap	170.05	25.6504	123.22	212.69
pea	39.4	0.879	38.03	40.59
palu	3268.91	3911.013	127.68	11905.23
depsante	34.7	5.477	25.61	42.70
educ	74.86	9.737	55.88	84.91
ouv	67	4.539	59.75	78.56

One of the conditions for an OLS regression of a time series model is that the variables in the model are stationary. It appears that the variables used are all integrated of order 1. The coefficients of the regression (elasticity) mean that if the explanatory variable changes by one percent, holding the other variables constant, then this coefficient corresponds to the percentage change in the explained variable (GDP per capita). Marginal effects indicate how much the dependent variable (GDP per capita) changes when the independent variable in question increases by one unit, holding all other variables in the model constant. Marginal effects are obtained using the Gujarati [15] formula:

$$\left(\frac{\overline{pibt_t}}{\overline{VE_i}}\right).\alpha_i \tag{6}$$

With $\overline{pibt_t}$ the mean of the dependent variable, GDP per capita; $\overline{VE_i}$ the mean of the ith explanatory variable; αi the log elasticity of the dependent variable under consideration. Moreover, we can notice in passing that we had to specify first a model without interaction (model1) before a model considering interactions. In fact, the collinearity between the variables involved in the interaction sometimes renders all their coefficients simultaneously zero, whereas the variables can exert significant distinct effects (Bressoux P., 2008). Only the model without previous interaction is able to indicate these effects. Indeed, the coefficients of the second model are "conditional" because their value is conditional on the values of the other variables involved in the interaction. This is not the case in a model that does not specify an interactivity between variables. In such a model, the coefficient of a variable is constant whatever the values of other variables taken into account in the model. If interactivity is specified, there is a moderating variable or variable that "changes" which corresponds to the variable whose changes induce a variation in the behaviour of the other variables with respect to the dependent variable [16] ?(Bressoux P., 2008).

4. RESULTS

4.1 Estimating the Macroeconomic Effects of Malaria in Senegal

The regression giving the coefficients (elasticity) and marginal effects to determine the direct effect is presented in Table 2. On the same table, we have presented the estimation of the interaction between malaria and the production factor to analyse the indirect effect of malaria through the potential loss of productivity.

4.1.1 The direct effect of malaria morbidity on Gross Domestic Product (GDP)

The econometric results prove the negative effect of malaria on the economy. Indeed, malaria has a negative and significant impact on the level of income, thus proving the burden of the disease in Senegal. Thus, when the incidence of malaria (per 10000) increases by 1%, the level of wealth created per capita decreases by 0.115% per year, when the other variables taken into account remain constant. This represents a significant loss of income for the well-being of the population. In fact, the calculation of the marginal effect of malaria shows that, all other things being equal, an increase in malaria of 1 unit leads to a decrease in GDP per capita of US$ 0.00467 per year, holding other variables constant. This result applied to the total GDP for the year 2018 (of US$ 23.24 billion) constitutes a total loss of US$ 108.53 million. This is a significant loss of GDP for a poor country like Senegal.

In the context of the study, other variables significantly explain the changes in GDP per capita. The factors of production, physical capital and labour, contribute positively to the creation of wealth in the economy. Indeed, a 1% increase in investment per capita in the country increases the production of goods and services by 0.0237%. More specifically, the increase in wealth corresponding to a unit increase in investment per person is US$0.1029 per year. The estimates show a relatively large contribution from the share of the working population in the total population. A 1% increase in this factor leads to an improvement in wealth creation of 1.09%, i.e. an annual contribution of the economically active population to the improvement in GDP per capita of US$20.4382. Educational human capital, the level of primary education, positively and significantly affects the output of the economy. Health expenditure is insignificant.

4.1.2 The effect of malaria on production through its effect on labour input (the indirect effect)

In order to complete this cost, it is necessary to present the results of the analysis of the interactivity that will allow us to analyse the effect of malaria on labour productivity. Indeed, we can observe that the variables not concerned by the elaboration of the interactive variable keep the same coefficients as in the model not specifying interactivity. Given the significance linked to the interactive variable, we can then confirm that the contribution of the economically active population is linked to the impact that malaria can have on this part of the population. This dependence of the contribution is given by:

$$\frac{\partial \log\_pibt\_d1}{\partial \log\_pea\_d1} = 0{,}616 - 0{,}475 \log\_palu\_d1 \qquad (7)$$

Thus, when the incidence of malaria increases, the contribution of labour to the production of goods and services is negatively affected. Thus, the indirect effect (or indirect costs), analysed in approaches to estimating the economic cost of a disease as the potential loss of productivity induced by the disease, is captured in our study by the decrease in the contribution of the labour force when malaria increases.

Thus, when the incidence of malaria increases by 1%, the elasticity of growth domestic product (“pibt” variable) with respect to pea is 0.611. Thus, when the incidence of malaria increases by 1%, the elasticity of gdp with respect to pea is 0.611%, with the other variables held constant. Therefore, there is a decrease in the elasticity of gdp with respect to pea when the effects of malaria on labour input are taken into account. Malaria-related effects therefore affect the productivity of labour input. This loss of labour productivity is reflected in the decrease from 1.091% (regression1 without the interaction) to 0.611% (with the interaction), or 0.48 percentage points (=1.091% - 0.611%). Thus, when we take into account the effect of malaria on the active proportion of the population, we observe the attenuation of the contribution of this labour factor to the production of goods and services. That is, in the case of a 1% increase in malaria, with the malaria-labour force interaction taken into account and other factors held constant, the contribution that resulted from a 1% increase in the proportion of the labour force falls by 0.48%.

It should be noted that the coefficient associated directly with the log_pea variable cannot be interpreted directly as in the case of model 1. Indeed, the sensitivity (or elasticity) of the gdp in relation to the eap is a function of the incidence of malaria (log_palu1). Thus, this coefficient (0.616) corresponds to the contribution of the pea when the log incidence of malaria is non-existent. Similarly, the coefficient attached directly to malaria (0.474) is not obtained by determining the elasticity in double logarithm form[3]. Indeed, this coefficient would mean that a proportion of people available for production is considered non-existent. It is within this framework that the coefficient corresponding directly to the variable giving the interactive variable is only to be considered in the case of analysis in relation to the interaction variable [16]. That is, the behaviour of this variable, pea, in relation to changes in malaria incidence in this study.

Thus, $\frac{\partial \log\_pibt\_d1}{\partial \log\_palu\_d1} = 0{,}474 - 0{,}475 \log\_pea\_d1$ (8)

4.2 Discussion

Malaria is not only a public health problem, but also an important development challenge for endemic countries. Indeed, the negative impact of malaria on the level of national income can be explained by the fact that this disease affects the volume and productivity of inputs. At the most direct level, malaria makes part of the labour force unproductive. This is confirmed by estimates that show a drop in production when malaria affects the working population. The loss of labour input was the subject of the first research on such a topic in relation to malaria [17] before further studies were reserved for it. The consensus on this negative aspect of malaria on the wealth level of country through the

[3] Considering the incidence of malaria when the economically active population is taken into account

Table 2/ Direct (model1) and Indirect (model2) effect of Malaria "palu"

	Model 1	**Model 2**
Variables	**Log_pibt_d1**	**Log_pibt_d1**
log_cap_d1	0.0237**	0.0237**
	(0.00889)	(0.00889)
log_pea_d1	1.091***	0.616***
	(0.03849)	(0.04918)
log_palu_d1	-0.002**	0.474***
	(0.00067)	(0.01189)
log_edu_d1	0.041***	0.041***
	(0.00426)	(0.00605)
Log_depsante_d1	0.013	0.013
	(0.01206)	(0.01206)
Log_ouv_d1	-0.022*	-0.022*
	(0.01165)	(0.01165)
Log_palu-pea_d1		-0.475***
		(0.05784)
Constant	3.283***	5.172***
	(0.08186)	(0.07291)
Observations	536	333
R-squared	0.4561	0.4388

Standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1*

effect on workers' productivity depends on the severity. Thus, this loss of productivity is generally due to the loss of working days followed by a decrease in working capacity for additional days or convalescence [18,19].

In Senegal, the 2011 poverty monitoring survey shows that malaria, accounting for more than 25.5% of the causes of illness, is one of the health problems that forces those affected to remain inactive for 7 to 14 days. The effect on production as a result of this loss of working time depends both on the degree to which other family members with affected persons can increase their work effort. In the context of Senegal, where the activity is predominantly agricultural in rural areas, this effect on production is further reinforced by the simultaneity observed between malaria episodes and the harvest period [20].

In addition, the significance of the interactivity confirms that the direct effects are to be added with other indirect effects such as the one detected, namely the link between malaria and productivity. The frequency of absenteeism reduces the efficiency of the labour circuit, especially when it leads to a reduction in agricultural capacity during periods of high production in this sector [21]. In fact, although the economically active population may be composed of unoccupied people, this does not prevent an ill person from pushing the occupied to take care of them. Thus, in addition to the monetary expenditure, care-seeking generally results in a loss of working time, which can affect the efficiency of work [22-32].

As for the other variables, it can be noted that trade openness has a negative effect on GDP per capita as found by Orem et al. [13] for Uganda. This is justified by the fact that Senegal is one of the countries that imports more than it exports, so openness is more beneficial for others who trade with Senegal. Primary education has a positive effect on national income, particularly because, as found for Bangladesh by Grira H. (2006), primary educated workers are more numerous in low-income countries and being literate leads them to further develop other sectors of the economy in the future. The capital and labour factor, likewise, affects the economy in that it allows for increased investment and savings in the economy. In fact, more investment and MOD available for the production of goods and services strengthen the competitiveness of the economy if it is well exploited.

5. CONCLUSION

Health is considered "priceless", but its depreciation due to disease still has a cost both socially and economically. Malaria is a curable and preventable disease, although still without a vaccine, which is a real public health problem in sub-Saharan Africa (SSA) and in Senegal in particular. In fact, the growing interest in academic studies on the analysis of malaria-related costs are explained by the desire to account for the economic consequences correlated to this disease, which has long been a major social concern of the Senegalese government. Senegal is characterised by a stable endemicity of malaria with peaks of cases during the rainy season.

This research is based on a macroeconomic perspective of estimating the cost of a disease. Thus, the production function approach through a double logarithmic model with interaction effect is used to estimate the economic burden of malaria. In order to prove the existence of indirect effects of malaria on labour productivity, an interactive variable estimation linking malaria and labour available for production was performed.

The econometric estimates show evidence of a negative impact of malaria on the economy and more precisely on the level of wealth of the country. This proves the burden of the disease in Senegal. The total loss of wealth directly related to malaria is estimated at USD 108.53 million per year. In addition, there is a drop in productivity as evidenced by the decrease in the contribution of labour to production. Indeed, when malaria increases in terms of incidence, this leads to a decrease in the contribution of labour to the production of wealth. Indeed, the results show a 0.48% decrease in labour productivity when there is a combined 1% increase in the malaria index.

The main lesson of this study is that malaria remains a major cause of wealth losses in Senegal until it is eradicated. In fact, in addition to the economic burdens that this disease induces, it also reduces the productivity of the labour force and thus their contribution to production. Indeed, at the macroeconomic level, the indirect cost includes aspects of the loss of productivity. Such consequences due to malaria can lead in the long term to adverse effects on economic growth, on efforts to fight poverty and thus on Senegal's socio-economic development. In fact, it would be interesting to analyse in future studies the impact of malaria on poverty dynamics in Senegal in order to extend the analyses to other incidences of malaria.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDIX

- Test of stationarity of series.

Decision rule: The variable is stationary if the probability is below the critical value; otherwise, we look at the first difference.

Conclusion: all variables are integrated of order 1, and then variables first differences (_d1) are used.

```
. dfuller log_pibt

Dickey-Fuller test for unit root                   Number of obs   =        24

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.353            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.6047


. dfuller log_pibt_d1

Dickey-Fuller test for unit root                   Number of obs   =        23

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.020            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0013

. dfuller log_cap

Dickey-Fuller test for unit root                   Number of obs   =        24

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.555            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1027

. dfuller log_cap_d1

Dickey-Fuller test for unit root                   Number of obs   =        23

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.744            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0001
```

```
. dfuller log_pea

Dickey-Fuller test for unit root                   Number of obs   =        24

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.378            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.5927

. dfuller log_pea_d1

Dickey-Fuller test for unit root                   Number of obs   =        23

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.241            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0006
. dfuller log_palu

Dickey-Fuller test for unit root                   Number of obs   =        24

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.504            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.5318

. dfuller log_palu_d1

Dickey-Fuller test for unit root                   Number of obs   =        23

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.022            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0329
```

```
. dfuller log_educ

Dickey-Fuller test for unit root                   Number of obs   =        24

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             1.291           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9966

. dfuller log_educ_dl

Dickey-Fuller test for unit root                   Number of obs   =        23

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -2.939           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0410
. dfuller log_ouv

Dickey-Fuller test for unit root                   Number of obs   =        24

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -2.055           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2629

. dfuller  log_ouv_dl

Dickey-Fuller test for unit root                   Number of obs   =        23

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -4.840           -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

```
. dfuller log_depsante

Dickey-Fuller test for unit root                   Number of obs   =        24

                          ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
              Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.484            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.5415

. dfuller log_depsante_dl

Dickey-Fuller test for unit root                   Number of obs   =        23

                          ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
              Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.675            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0045
. dfuller log_palu_pea_

Dickey-Fuller test for unit root                   Number of obs   =        24

                          ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
              Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.513            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) - 0.5272

. dfuller log_palu_pea_dl

Dickey-Fuller test for unit root                   Number of obs   =        23

                          ---------- Interpolated Dickey-Fuller ---------
                 Test         1% Critical       5% Critical      10% Critical
              Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.996            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0352
```


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