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Analyzing the impact of external debt on industrialization : the African franc zone case

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Abstract. This paper uses data from 10 countries of the African franc zone from 1996 to 2017, to gauge the effect of external debt on industrialization in the presence of non-linearity. Our analyzes are done based on two aspects. Firstly, using a Panel Smooth Transition Regression (PSTR), our results show that there is a non-linear relationship between external debt and industrialization in the African franc zone, which depends on the level of the external debt stock, the threshold is 58.91% of GDP. While before this threshold, external debt has no direct effect on industrialization, after this threshold it is harmful to it. Secondly, an analysis in two periods (1996-2006 and 2007-2017) by the GLS and SUR methods shows that before 2006, the external debt was an asset for industrialization but after, it gave way to domestic credit. Thus, the external debt has become obsolete after reaching the completion point of the HIPC initiative, and would be a danger for the industrialization of the franc zone in the event of excess.

Key words: solvency; liquidity; manufacturing value added; budget deficit; Panel Smooth Transition Regression (PSTR); African Franc Zone.
AMS 2010 Mathematics Subject Classification Objects : 62Fxx; 62Gxx; 62Jxx.

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Résumé. (Abstract in French) Ce travail utilise les données de 10 pays de la zone franc africaine sur la période 1996-2017, pour jauger l'effet de la dette extérieure sur l'industrialisation en présence de non linéarité. Nos analyses sont faites suivant deux aspects. Premièrement, en utilisant un modèle de panel à transition souple (PSTR), nos résultats montrent qu'il existe une relation non linéaire entre la dette extérieure et l'industrialisation en zone franc africaine, qui dépend du niveau du stock de dette extérieure dont le seuil est de 58.91% du PIB. Alors qu'avant ce seuil, la dette extérieure n'a pas d'effets directs sur l'industrialisation, après ce seuil elle lui est nuisible. Deuxièmement, une analyse en deux périodes (1996-2006 et 2007-2017) par les méthodes GLS et SUR montre qu'avant 2006, la dette extérieure était un atout pour l'industrialisation mais après, elle a laissée place au crédit domestique. Ainsi, l'endettement extérieur est devenu désuet après atteinte du point d'achèvement de l'initiative PPTE, et serait un danger pour l'industrialisation de la zone franc en cas d'excès.
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1. Introduction

Since the improvement of oil prices in the 1970s, African countries in the Franc zone have contracted huge foreign loans to modernize their economies. In their strategy, these countries have favored self-centered development with an industrialization that aims at prioritizing local consumption. Since most African products are not competitive on international markets, the industrialization strategies adopted since then have not produced the expected results. An examination of the causes of this slow process of industrialization shows that some countries contracted debt to import basic necessities, fill their budget deficits and therefore directed it towards either non-productive expenditures or that prevent the development of local industry.

The choice of the African Franc zone is justified by at least three reasons. Indeed, of the 41 countries classified as HIPC, 33 are in sub-Saharan Africa, including 13 of the economies of the Franc zone (see Nounamo(2019)). The African countries of the Franc zone have benefited from more external financing than the other sub-Saharan African countries, due to monetary cooperation with France (Beah A. (2015)). According to World Bank data (2016, 2017, 2018), the largest borrowers in the sub-Saharan African region are located in this zone. However, since the publication of the World Bank's first "Doing Business" report in 2004, most African countries in the Franc zone have always found themselves in the last

quarter of the ranked economies, and according to the 2018 edition's ranking, these countries are among those that, despite efforts, have not seen any significant improvement. From the point of view of their level of solvency and liquidity, it should be noted that the drop in oil prices by 52% between 2014 and 2016 in the CEMAC zone (IMF (2017)), accompanied by the weakness of their exports and the fall in foreign exchange reserves in the franc zone also contributed to reducing the credibility of these countries with donors.

Moreover, the emergence objectives of these countries require huge capital and infrastructure expenditures, which are still mostly financed by external debt. Several donors confirm the vulnerability of these countries in general, and even more of the oil-producing countries in the zone (IMF (2017); World Bank (2018)), in the light of past and present crises. They recommend structural transformation and, to achieve this, to make their debt productive. But productivity should mean industrialization, because the industrial sector is generally the sector with the highest returns on scale. We therefore wish to contribute to the debate on the impact of foreign debt on developing economies by analyzing the impact of foreign debt on the industrialization of the Franc zone countries in the presence of non-linearity.

Thus, following Oumou(2016), we used a flexible transition panel (FTP) modeled by Gonzalez *et al.* (2005). This model has the advantage of being able to find thresholds dividing regimes where the relationship between the variable of interest and the explanatory variables differs. The non-linearity question refers to a situation in which one or more economic variables no longer have a unique effect on the variable of interest, since their effects differ according to the situations in which the economy finds itself. Such situations can be for example, a period of high indebtedness as opposed to a situation of moderate external indebtedness. External indebtedness is measured by the debt/GDP ratio and industrialization by the ratio of manufacturing value added to GDP. After prior verification tests, we have used external debt as a percentage of GDP as a transition variable. The data used in this work come from two secondary sources which are the WDI and WGI databases of the World Bank, over the period 1996-2017 and for the countries of the African franc zone.

The rest of this paper makes a brief literature review in section 2, presents the methodology used in section 3, followed by the results section which starts with the description of our variables and the preliminary analysis of non-linearity and ends with the presentation of the results. The last section (section 5) concludes this paper by making recommendations as a policy for financing industrialization.

2. Literature review

Several economic theories justify the role of external debt in the industrialization of a country. While the Keynesians think that a debt-financed budget deficit can improve the confidence of agents, encourage investment and therefore promote

industrialization, the classics, find that foreign debt is pernicious, constitutes a tax on future generations and therefore discourages investment and therefore industrialization. A synthetic vision of Ricardian equivalence developed by Barro (1974) states that the positive and negative effects of debt neutralize each other, so that foreign debt no longer has any effect on industrialization. In fact, according to this theory, when the State acquires a loan, agents anticipate a future tax and take precautions. The incentive to invest decreases and consequently the positive effects due to the public investment generated are offset by the negative effects due to the slowdown in economic activity.

A relatively recent school of thought on the question of external debt, supported by Mama (1985), Sachs J. (1989), Krugman P. (1989), discusses the notion of a sustainable debt threshold for an economy and presents an equivalent to the *Laffer* curve for public debt.

Several industrialization strategies have been presented in the literature, within the framework of development. The best known are :

- **Industrialization by Import Substitution (ISI)** : this first strategy is thought within the framework of self-centered development and consists in practicing an industrialization strategy aimed primarily at local consumption. This strategy can contribute to increase external debt because of the need for capital and technology necessary for its implementation.
- **Industrialization through Export Promotion (IPE)** : It consists of the conquest of the external market, in order to increase exports. To succeed in this strategy, it is necessary that the corresponding countries are internationally competitive. However, it has the advantage of bringing in foreign currency, which is useful for the payment of foreign debt service.
- **Industrialization by Industrializing Industries (III)** : it consists in the creation of industries in order to generate spillover effects on others. It falls within the framework of the theories of unbalanced development.

The literature on industrialization strategies adopted since independence by African countries of the franc zone shows the difficulty of their implementation. Indeed, the ISI strategy has proven to be unsuitable for such countries directly after their independence, because such a strategy enhances protectionism in order to promote local production. Unfortunately, local industrialization is in dire need of capital and technology. They have therefore turned to debt to ensure this need, which has sometimes had distorting effects on industrialization. The cost of external debt and the behavior of public agents who use it, as well as non-productive investments, are causes that are often pointed out [See Oumou(2016); Ndikumana & Boyce (2013)].

The transition to industrialization through export promotion has again come up against the problem of capital and technology deficits followed by indebtedness in these countries. Policies to boost consumption through food imports and opening

up to foreign companies have further destroyed the nascent and embryonic national industrial fabrics. In addition, the companies entering the Franc zone countries were mostly extractive.

A good strategy of industrialization by the industrializing industries has not yet been established in the AFZ. Indeed, such a strategy would not only lead to a development of equilibrium, but would also reduce the possibility of broadening the tax bases of these countries.

Oumou(2016) shows using a threshold effect panel (PSTR) model that there is a threshold effect of public debt on industrialization in the WAEMU. He therefore determines an optimal debt level for these countries The level from which any additional indebtedness will weigh on the economic performance of the countries of the Union], which is 80%. He uses the external debt-to-GDP ratio as a transition variable and as an explanatory variable that changes according to the regime. Assuch, according to the regime, above this threshold, debt has a negative and significant impact on growth in WAEMU countries. However, below this threshold, the effect of debt on growth in WAEMU countries is positive and not significant.

According to Onyeiwu & Karonga (2013), many studies on the industrial performance of African countries are based on either descriptive analyzes or case studies, but very few are well formulated models explaining industrialization as a function of other factors, as in the case of growth. They use Lucas(1988) model as theoretical model on which their empirical analysis is based.

Following the literature review on the determinants of industrialization, we specify the empirical model of industrial growth in the African franc zone by adding trade, macroeconomic stability variables (external debt,inflation, etc.), infrastructure, institutional innovation and market size to Lucas' model. We use a threshold effect specification in order to take into account the impact of the external debt in case of sustainable debt and its impact otherwise. To do so, a transformed expression of the external/GDP ratio (with the help of a logistics function) is cross-referenced with the external debt itself and other analysis variables. The empirical methodology used is presented below.

3. Panel Smooth Transition Regression

3.1. The simple panel model

Panel data are observations of a set of individuals observed on several dates. In contrast to cross-sectional data or time series, having data in both dimensions has the following advantages :

- control of the individual heterogeneity : the analyzes in instantaneous sections and time series do not control these individual effects and therefore can produce biased results.

- more information, more variability and less col-linearity between variables, more freedom and more efficiency of estimates;
- more adequate to study the dynamics of adjustment: the data in instantaneous sections, although seemingly stable, hide a multitude of changes;
- more able to identify and measure effects that are not detectable in cross-sectional data or time series;
- allows the construction and testing of more complicated theoretical and conceptual models than the two previous data types;
- gives more adequate measures for micro-economic data than adequate estimates on macroeconomic data.
- gives a statistic for the unit root test on macro-panels with a long time dimension, whose asymptotic distribution is standard, unlike the time series.

Thus, for a sample of individual observations whose individuals are indexed by $i = 1, \cdots, N$ and the temporal dimension indexed t with $t = 1, ..., T$, assuming that there is no attrition or missing observations (panel cylinder), the standard panel model is written :

$$y_{it} = x_{it}\beta + z_i\alpha + \epsilon_{it} \tag{1}$$

where y is the explained variable (in our case, the share of manufacturing value added in GDP). The k explanatory variables of the model are grouped in k vectors x_{it} of dimension $(1, k)$ (which does not include the unit vector) and are assumed to be exogenous. The vector β of dimension $(k, 1)$ denotes the vector of unknown parameters to be estimated. The heterogeneity, or individual specific effect, is captured by the term $z_i\alpha$. The vector z_i includes a constant term and a set of variables specific to individuals, invariant in time (example: sex), which may or may not be observed (example: preferences). The hypotheses formulated on the error terms depend on the type of model considered. Indeed, depending on the nature of the variables taken into account in the vector z_i, three classes of models can be considered: the linear model on pooled data, the fix-effects model and the random-effects model. The first type of model corresponds to the case where z_i only includes the constant 1 :

$$y_{it} = x_{it}\beta + \alpha + \epsilon_{it} \tag{2}$$

where $\epsilon_{it} \sim \aleph(0, \sigma)^2$. The individual heterogeneity is not modeled; the specification leads to a simple stacking of the data in cross-sections. In this case, a convergent and efficient estimator of b and a is obtained by the Ordinary Least Squares (OLS) method.

In the fix-effects model, the individual heterogeneity is modelled by taking into account specific individual effects constant over time. This model is written :

$$y_{it} = x_{it}\beta + \alpha_i + \epsilon_{it} \tag{3}$$

where the individual fix-effect reflecting a conditional average is a parameter to be estimated, constant over time and $\epsilon_{it} \sim \aleph(0, \sigma)^2$. In this model, unobservable behavioural differences are thus captured by these estimable parameters. This model is then particularly suitable when the sample is exhaustive with respect to the population it concerns and the modeler wishes to restrict the results to the sample that allowed them to be obtained [See Baltagi(2013)]. These hypotheses are verified in the case of African Franc Zone countries, since we have chosen a representative sample of these countries.

The individual effects α_i can be correlated with the explanatory variables x_{it}. In this case, we use the within estimator [Estimator of OLS obtained from a model where the explanatory and explained variables are centered on their respective individual average.] and it is convergent.

In the third model, with random effects, the individual heterogeneity is modeled by taking into account specific individual random effects (constant over time). It is hypothesized that this unobservable individual heterogeneity is not correlated with x_{it} :

$$y_{it} = x_{it}\beta + u_{it}; u_{it} = \alpha_i + \epsilon_{it} \tag{4}$$

where $\epsilon_{it} \sim \aleph(0, \sigma^2)$. In contrast to the fixed-effects model, individual effects are no longer parameters to be estimated, but realizations of a random variable. This model is therefore suitable if individual specifics are linked to random causes. It is also preferable to the fix-effects model when the individuals in the sample are drawn from a larger population and the objective of the empirical study is to generalize the results obtained to the population. This model has the advantage of providing more accurate estimates than those obtained from the fix-effects model. It is usually estimated using the Generalized Least Squares Method (GLS).

Simple panel data also has limitations that are mainly due to the difficulty of having data on same individuals over time [When an individual leaves the observed panel at a given date (death, $\cdots$, etc), this is called attrition effect] and the high cost of collecting them. Another limitation is the inability to take into account structural changes in the data and the regime changes in the relationship between two or more variables. Below is described the general PSTR model, as defined by Gonzalez et al.(2017).

3.2. The Panel Smooth Transition Regression : PSTR

3.2.1. General principle of the model

The Panel Smooth Transition Regression (PSTR) model can be viewed as a linear model based on heterogeneous panel data with coefficients that vary between individuals and over time. The heterogeneity of the coefficients of the model is considered under the assertion that, these coefficients are bounded continuous functions of an observable variable, called a transition variable. This makes them

vary between a limited number of extreme regimes. Since the transition variable can be a variable specific to the individual dimension or the time dimension, the regression coefficients can be different for each individual and change over time. In the context of this study, we adopt the first interpretation.
The basic PSTR model with two extreme regimes is defined as follows :

$$y_{it} = \mu_i + \lambda_t + \beta_0^{'} x_{it} + \beta_1^{'} x_{it} g(q_{it}; \gamma, c) + u_{it} \tag{5}$$

For $i = 1, \ldots, N$, and $t = 1, \ldots, T$, where N and T, are respectively the number of countries in the panel and the total number of years. The dependent variable y_{it} is a scalar, x_{it} is a k-dimensional vector of time-varying exogenous variables, μ_i and λ_t denote the individual and temporal fixed effects, and u_{it} denotes the error term. The variables x_{it} are assumed to be exogenous.

The transition function $g(q_{it}; \gamma, c)$ is a continuous function of the observable variable q_{it} and is normalized to be bounded between 0 and 1. The two extreme values are associated with the regression coefficients β_0 and $\beta_0 + \beta_1$. More generally, the values of the transition variable q_{it} determine the values of $g(q_{it}; \gamma, c)$ such that, the effective regression coefficients are $\beta_0 + \beta_1 g(q_{it}; \gamma, c)$ for the individual i at time t. We use the logistic specification for the function g :

$$g(q_{it}; \gamma, c) = (1 + exp(-\gamma \pi_{j=1}^{m} (q_{it} - c_j)))^{-1} \text{ with } \gamma > 0 \text{ and } c_1 < c_2 < \cdots < c_m, \tag{6}$$

where $c = (c_1, \ldots, c_m)$ is a vector of dimension m with position parameters and the slope parameter γ determine the speed of transitions. In practice, it is commonly sufficient to take $m = 1$ or $m = 2$, since these values allow any type of variations of the parameters. For $m = 1$, the model highlights two extreme regimes associated with low and high values of the transition variable q_{it} with a monotonic transition of coefficients from β_0 to $\beta_0 + \beta_1$ when q_{it} increases, where the variations are centered around c_1.

When $\gamma \to \infty$, $g(q_{it}; \gamma, c)$ becomes the indicator function $I_{[q_{it} > c_1]}$ (which is 1 if $q_{it} > c_1$ and 0 otherwise). In this case, the PSTR model is reduced to a two-regime model by Hansen(1999). For $m = 2$, the transition fonction has its minimum at $c_1 + c_2/2$ and reaches its maximum simultaneously for small and large values of q_{it}. When $\gamma \to \infty$, the method becomes a three-regime threshold effect model where the extreme regimes are identical and different from the intermediate regime, which allows to limit itself to a two-regime model. In general, when $m > 1$ and $\gamma \to \infty$, the number of distinct regimes is limited to two, with the transition function fluctuating between 0 and 1 for $c_1, \ldots, c_m$. Finally, for any positive integer value of m, the transition function (6) becomes constant when $\gamma \to 0$, in this case the model is reduced to a panel fix-effect linear model.

A generalization of the PSTR model in case of more than two regimes is the following model :

$$Y_{it} = \eta_{it} + \lambda_{it} + \beta_0^{'} x_{it} + \sum_{j=1}^{r} \beta_j^{'} x_{it} g_j(q_{it}^j; \gamma_j, c_j) + u_{it}, \tag{7}$$

where the transition functions $g_j(q_{it}^j; \gamma_j, c_j)$,$j = 1, \ldots, r$, are defined by (6) with polynomial degree m_j. If $m_j = 1, q_{it}^{(j)} = q_{it}$, and $\gamma \to \infty$ for all $j = 1, \ldots, r$, the model (7) becomes a PTR [model with several indicators instead of transition functions] model with $r + 1$ regimes. Consequently, the generalized PSTR model can be seen as a generalization of the multi-regime panel model presented by Hansen(1999). Moreover, when the model to be considered is a two-regime PSTR of (5) with r=1 and m=1 or m=2, model (7) is useful for the evaluation of the estimated model. More specifically, the multi-regime model (7) is a natural alternative hypothesis for the remaining non-heterogeneous diagnostic test.

3.2.2. PSTR model implementation

a) Model specification and homogeneity test.

The initial test to be carried out is the homogeneity test against the alternative of a PSTR model. Indeed, the PSTR model is not identified if the generating process of data is homogeneous, the test of homogeneity is therefore a prerequisite. The PSTR model (5) with (6) can be reduced to a homogeneous model by imposing either $H_0 : \gamma = 0$ or $H_0^{'} : \beta_1 = 0$. The position parameters c_j are not identified under the null hypothesis, and this is also the case for β_1 under H_0 and for γ under the $H_0^{'}$ hypothesis. The authors test the homogeneity using the null hypothesis $H_0 : \gamma = 0$. To avoid the identification problem, they replace $g(q_{it}; \gamma, c)$ of (5) by its Taylor's expansion of order one in the neighborhood of $\gamma = 0$. After re-parametrization, this returns to the auxiliary regression :

$$y_{it} = \mu_i + \lambda_t + \beta_0^{'*} x_{it} + \sum_{j=1}^{m} \beta_j^{'*} x_{it} q_{it}^j + u_{it}^*, \tag{8}$$

where the parameter vectors $\beta_1^*, \ldots, \beta_m^*$ are multiples of γ, and $u_{it}^* = u_{it} + R_m \beta_1^{(}*) x_{it}$ Where R_m is the rest of Taylor. Therefore, testing $H_0 : \gamma = 0$ in (5) is equivalent to testing the null hypothesis $u_{it}^* = u_{it}$.
To define the Lagrange Multiplier (LM-test) test statistic used for this test, equation (8) is rewritten in the following sum matrix notation :

$$y = D_\eta \eta + X\beta_0^* + W\beta^* + u^* \tag{9}$$

Where, $\beta = \beta_0^*$ et $\beta^* = (\beta_1^{'}, \ldots, \beta_m^{*'})^{'}$,
$w_{it} = (x_{it}^{'} q_{it}^{(1)}, \ldots, x_{it}^{'} q_{it}^{(m)})$ et $u^* = (u_{it}^*, \ldots, u_{iT}^*)$.
The LM-test have statistic $\hat{u}_0^{'} \tilde{W} \hat{\Sigma}^{-1} \tilde{W}^{'} \hat{u}_0$ where $\hat{u}^0 = (\hat{u}_1^{0'}, \ldots, \hat{u}_N^{0'})^{'}$ is the residual vector obtained by estimating the model under the null hypothesis, $\tilde{W} = M_\mu$ with

M_μ=$I_{NT} - D_\mu(D_\mu^{'}D_\mu)^{-1}D_\mu^{'}$ the standard matrix of the within transformation, and $\hat{\Sigma}$ is a consistent estimator of the variance covariance matrix $\Sigma = (\hat{\beta}^* - \beta^*)(\hat{\beta}^* - \beta^*)^{'}$. When the errors are homoscedastic and identically distributed over time and between individuals, the standard covariance matrix estimator

$$\hat{\Sigma}^2 = \hat{\sigma}^2(\tilde{W}^{'}\tilde{W} - \tilde{W}^{'}\tilde{X}(\tilde{X}^{'}\tilde{X})^{-1}\tilde{X}^{'}\tilde{W}), \tag{10}$$

where $\tilde{X} = M_\mu X$ et $\hat{\sigma}^2$ is the estimated error variance under the null hypothesis. When the errors are heteroscedastic or auto-correlated, an appropriate estimator of $Sigma$ is given by

$$\hat{\Sigma}^2 = [-\tilde{W}^{'}\tilde{X}(\tilde{X}^{'}\tilde{X})^{-1} : \hat{\Delta}[-\tilde{W}^{'}\tilde{X}(\tilde{X}^{'}\tilde{X})^{-1} : I_{km}]^{'} \tag{11}$$

where [":" denotes column matrix concatenation with the addition of I_{km} on the right to form a new matrix I_{km}] and where I_{km} is an identity matrix $(km \times km)$, and $\hat{\Delta} = \sum_{i=1}^{N} \tilde{Z}_i^{'}\hat{u}_i^0\hat{u}_i^{0'}\tilde{Z}_i$ with $\tilde{Z}_i = (I_T - l_T[l_T^{'}l_T]^{-1}l_T^{'})Z_i$, where $\tilde{Z}_i = [X_i, W_i], i = 1, ..., N$ and l_T is a column matrix of dimension $1 \times T$ containing only 1's.
Estimator 11 is consistent for a fixed T when $N \to \infty$ [See Hansen(2007)] presents a detailed analysis of the remaining cases.. Under the null hypothesis, LM_χ is asymptotically distributed following a $\chi^2(mk)$, while its Fisher's version $LM_F = LM_\chi(TN - N - k - mk) \setminus (TNmk)$ has an approximate Distribution of Fisher's Law $F(mk, TN - N - k - mk)$.

Two remarks concerning the homogeneity test are necessary. First, the test can be use to select the appropriate transition variable q_{it} in the PSTR model. In this case, the Taylor expansion test is performed for a set of "candidates" transition variables and the variable that gives rise to the strongest rejection of the linearity (if any) is selected as the transition variable. Secondly, the homogeneity test can also be used to determine the appropriate order m of the logistic transition function in (6). This can be done as follows: Using auxiliary regression (8) with $m = 3$, test the null hypothesis $H_0^* : \beta_3^* = \beta_2^* = \beta_1^* = 0$. If it is rejected, test $H_{03}^* : \beta_3^* = 0, H_{02}^* : \beta_2^* = 0/\beta_3^* = 0$ and $H_{01}^* : \beta_1^* = 0/\beta_3^* = \beta_2^* = 0$, select m = 2 if the rejection of H_{02}^* is the strongest, otherwise select m = 1.

b) Parameters estimation

The estimation of the parameters $\theta = (\beta_0^{'}, \beta_1^{'}, \gamma, c^{'})$ in the PSTR model (5) is a combination of the fixed effects estimator and the non-linear least squares (NLS) estimator. Although the elimination of fixed effects using the Within transformation is the standard in linear models on panel data, the PSTR model requires more careful treatment. Rewrite model (5) as follows :

$$y_{it} = \eta_i + \beta^{'}x_{it}(\gamma, c) + u_{it}, \tag{12}$$

where $x_{it}(\gamma, c) = (x_{it}^{'}, x_{it}^{'} g(q_{it}; \gamma, c))^{'}$ and $\beta = (\beta_0^{'} - \beta_1^{'})$. Subtracting the individual averages from (12) yields :

$$\tilde{y}_{it} = \mu_i + \beta^{'} \tilde{x}_{it}(\gamma, c) + \tilde{u}_{it}, \tag{13}$$

where $\tilde{y}_{it} = y_{it} - \bar{y}_{it}$, $\tilde{x}_{it} = (x_{it}^{'} - \bar{x}_{it}^{'}, g(q_{it}; \gamma, c) - \bar{W}_i^{'}(\gamma, c))^{'}$,$\tilde{u}_{it} = u_{it} - \bar{u}_{it}$, and with $\bar{W}_i^{'}(\gamma, c) = T^{-1} \sum_{t=1}^{T} x_{it} g(q_{it}, \gamma, c)$,

As a consequence, the transformed vector $\tilde{x}_{it}(\gamma, c)$ in (13) depend on γ and c both in level and by individual averages. For this reason, $\tilde{x}_{it}(\gamma, c)$ must be recalculated at each iteration in the NLS optimization. According to (13), we see that the PSTR model is linear in β conditionally to γ and c. Thus, NLS is applied to determine the values of those parameters that minimize the concentrated sum of squared errors.

$$Q^c(\gamma, c) = \sum_{i=1}^{N} \sum_{t=1}^{T} (\tilde{y}_{it} - \hat{\beta}^{'}(\gamma, c) \tilde{x}_{it}(\gamma, c))^2 \tag{14}$$

where $\hat{\beta}(\gamma, c)$ is obtained from (13) by the ordinary least squares at each iteration of the non linear optimization. If the errors u_{it} of (12) are normally distributed, this estimation procedure is equivalent to a maximum likelihood (ML), where the likelihood function is first concentrated with respect to the fixed effects η_i.
The starting values for the NLS optimization are obtained by means of an iterative search among the parameters of the transition function $g(q_{it}, \gamma, c)$. This approach is based on the fact that (13) is linear in β when γ and c are fixed. Therefore, the concentrated sum square of residuals (14) can easily be calculated for a table ("Grid") of values for γ and c such that $\gamma > 0$, and $c_{j,min} > min_{i,t} q_{it}$ and $c_{j,max} < max_{i,t} q_{it}$, $j = 1, ..., m$, and the values minimizing $Q^c(\gamma, c)$ can be used as starting values of the non-linear optimization algorithm.

3.2.3. Model evaluation

The evaluation of an estimated PSTR model is an essential part of the model construction procedure, and in this sub-section we examine two specification tests for this purpose.

a) Parameter constancy test

In a panel model with a relatively large time dimension, it is necessary to test the constancy of the parameters. The PSTR model has the special feature of offering this possibility. The alternative to parameter constancy is that the parameters of (5) change slowly over time. The model under the alternative can be called the panel data regression model with smooth transition and time variation: "Time Varying Panel Smooth Transition Regression (TV-PSTR)", and it is defined as follows :

$$y_{it} = \gamma_i + (\beta_{10}^{'} x_{it} + \beta_{11}^{'} x_{it} g(q_{it}; \gamma_1, c_1)) + f(t/T; \gamma_2, c_2)(\beta_{20}^{'} x_{it} + \beta_{21}^{'} x_{it} g(q_{it}; \gamma_1, c_1)) + u_{it} \tag{15}$$

where $g(q_{it};\gamma_1,c_1)$ is defined in (6) and $f(t/T;\gamma_2,c_2)$ is another transition function of the same form as g.
When $\gamma_2 = 0$ in (15), $f(t/T;0,c_2) = 1/2$, the model defined in (15) has constant parameters and $H_0 : \gamma_2 = 0$ can be chosen as the null hypothesis of parameter constancy. An expansion is also applied and the tests LM_χ and LM_F presented above are used to verify this hypothesis. The corresponding statistic LM_χ follows a law of $\chi^2(2hk)$ and $LM_F = LM_\chi/2hk$ has an approximate distribution of $F(2hk, TN - N - 2K(h+1) - (m+1))$.

b) No remaining heterogeneity test

The hypothesis that a two-regime PSTR model (5) with (6) accounts for the heterogeneity of a set of panel data can be tested in different ways. Within the PSTR model, an additive PSTR model (7) with two transitions (r = 2) is considered as an alternative. Thus,

$$y_{it} = \gamma_i + \beta_0^{'} x_{it} + \beta_1^{'} x_{it} g_1(q_{it}^{(1)};\gamma_1,c_1) + \beta_2^{'} x_{it} g_2(q_{it}^{(2)};\gamma_2,c_2) + u_{it}, \tag{16}$$

where the transition variables $q_{it}^{(1)}$ and $q_{it}^{(2)}$ can be, but need not necessarily the same. The null hypothesis of no heterogeneity in a PSTR model estimated to two regimes can be formulated as $H_0 : \gamma_2 = 0$ in (16). This test problem is further complicated by the presence of unidentified nuisance parameters under the null hypothesis. As above, the identification problem is avoided by replacing $g_2(q_{it}^{(2)};\gamma_2,c_2)$ by a Taylor expansion about $\gamma_2 = 0$. This leads to the auxiliary regression

$$y_{it} = \eta_i + \beta_0^{*'} x_{it} + \beta_1^{'} x_{it} g_1(q_{it}^{(1)};\hat{\gamma}_1,\hat{c}_1) + \gamma_{21}^{*'} x_{it} q_{it}^{(2)} + \cdots + \beta_{2m}^{*'} x_{it} q_{it}^{(2)m} + u_{it}^{*}, \tag{17}$$

where $\hat{\gamma}_1$ and $\hat{c}_1$ are estimates under the null hypothesis. Since $\beta_{21}^{*};\ldots;\beta_{2m}^{*}$ are multiples of γ_2, the hypothesis of no remaining heterogeneity can be reformulated in $\beta_{21}^{*} = \cdots = \beta_{2m}^{*} = 0$. We also use LM_χ and LM_F statistics to perform this test. Under the null hypothesis, LM_χ for this test is asymptotically distributed according to a law of $\chi^2(mk)$ and LM_F has an approximate distribution of $F(mk, TN - N - 2 - K(m+2))$.

3.2.4. Finding the number of regimes

Parameter constancy and non-heterogeneity remaining tests can generally be used as erroneous specification tests in an additive PSTR model of the form (7) with $r > 0$. The purpose of no remaining heterogeneity test is thus twofold. It is a bad specification test, but also a useful tool to determine the number of transitions in the model. The following sequential procedure can be used :

- estimate a linear (homogeneous) model and test the homogeneity at a predicted and determined level of significance α;
- if the homogeneity is rejected, estimate a PSTR model with two regimes;

- test the hypothesis of no remaining heterogeneity for this model: If it is rejected at the level of significance $\tau\alpha$, with $0 < \tau < 1$, estimate an additive PSTR model with $r = 2$; The goal of reducing the level of significance by a factor τ is to avoid too large models;
- continue until the null hypothesis of no residual heterogeneity can no longer be rejected (using the significance level of $\tau^{r-1}\alpha$ when the additive PSTR model under the null hypothesis includes r transition function).

3.3. Unit root tests of Levin et al. (2002) versus Im, Pesaran and Shin (IPS, 2003)

Panel data has a temporal dimension that transfers to them the possibility of the presence of unitary roots. It is therefore necessary to verify that the average of the series involved in the analysis varies only by an insignificant amount, that their variance remains constant and that their auto-correlation depends only on the time lag. The Levin *et al.* (2002) tests followed by Im, Im, Pesaran and Shin (IPS, 2003), well known in panel analyzes, allow us to verify this property of stationarity.

The difference between these two tests is that the test of Im, Pesaran and Shin (IPS, 2003) takes into account the individual dependence. It can therefore be less efficient than that of Levin *et al.* (2002) if there is no individual dependence, but is less biased otherwise.

Principle of the individual dependence test of Pesaran (2004)
This test allows us to verify the presence or absence of cross-sectional dependence. The hypotheses are as follows: H0: "absence of cross-sectional dependency" against the alternative H1: "individual dependence". The test statistic is given by :

$$CD = \sqrt{\frac{2T}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \tilde{\rho}_{ij}} \tag{18}$$

Where

$$\tilde{\rho}_{ij} = \frac{T^{-1} \sum_{t=1}^{T} \tilde{u}_{it}\tilde{u}_{jt}}{\sqrt{T^{-1} \sum_{t=1}^{T} \tilde{u}_{it}^2} \sqrt{T^{-1} \sum_{t=1}^{T} \tilde{u}_{jt}^2}}$$

$\tilde{u}_{jt}$ is the calculated residual after regression. And under the hypothesis H0, the CD statistic asymptotically follows a reduced centered normal distribution. The rejection of H0 means there is individual dependence.

3.4. Data source

Overall, the database used for our analysis contains 10 African Franc Zone (AFZ) countries, which are observed over 22 years, from 1996 to 2017. The data come from the World Development Indicators (WDI) and Worldwide Governance

Indicators (WGI) databases of the World Bank. The AFZ is made up of CEMAC, WAEMU, and the Comoros Islands. Following the methodological approach, and drawing inspiration from the literature, we have selected 16 variables whose characteristics of central tendency are presented in Table 5 of the appendix. We note that overall, the other variables are not very dispersed (standard deviation close to the mean and lower than the mean for most of them). This fairly good dispersion may make it possible to control leverage effects whose potential source would be a high proportion of foreign debt in GDP or a low level of industrialization, for some countries such as Chad.

ManufVA_GDP : this is the manufacturing value added as a percentage of GDP. This variable has an overall mean of 9.96% with a standard deviation of 5.05. There is also an inter-individual [standard deviation of means per country]. standard deviation of 4.18 and an intra-individuel standard deviation (within[Deviation from the individual mean to which a global mean is added].) of 3.12. It is therefore not too scattered. We can also observe a minimum value of 0.23 for a maximum of 21.20. These figures reflect the fact that there are countries in the database that have experienced years of crisis in the manufacturing sector, while other countries have a fairly developed manufacturing sector.
Exterdebt_GDP : External debt as a percentage of GDP has a very scattered distribution (average of 66.92 for an overall standard deviation of 67.73). However, the interindividual standard deviation is lower than that of the intra-individual dimension (43.08 versus 53.94). This in fact reflects the almost homogeneous behavior of the countries in the database in terms of debt. There is therefore an overall minimum of 10.55% of GDP and a maximum of 470% of GDP, a value that Guinea-Bissau achieved in 1998. The countries that have already experienced values higher than 70% of GDP are: Guinea-Bissau, Guinea-Bissau, Guinea-Conakry, Guinea-Bissau, Guinea-Conakry and Guinea-Bissau: Guinea-Bissau (15), Ivoiry Coast(12), Togo(12), Congo (11), Cameroon (8), Niger(8), Gabon(5), Chad(2). The figures in brackets reflect the number of years over the last 20 years constituting the study period, where this has been observed.

Apart from these variables, we also had the Human Capital (HC) index, the share of workers aged between 15 and 64 years, the population and the indices of the quality of institutions. These variables generally have little scattered distributions and are fundamental in terms of literature for the analysis of the determinants of industrialization.

4. Results

In this section, after a description of the variables, we have performed logarithmic transformation on some variables in order to reduce their scale and to ensure a better non-linear approximation of their relations with industrialization. Thus, we retained for the continuation of the analysis the variables which do not only have a relation with industrialization, but which are not very correlated with the others (correlation $< 50\%$). Figure 7 in the appendix, presents an illustration of the

relationship of some selected variables with industrialization, before and after this transformation.

4.1. Descriptive analyses

4.1.1. Budgetary balance and external debt

Figure 1 presents the budget balance and public debt of Sub-Saharan Africa in comparison with the franc zone and its economic and monetary unions.

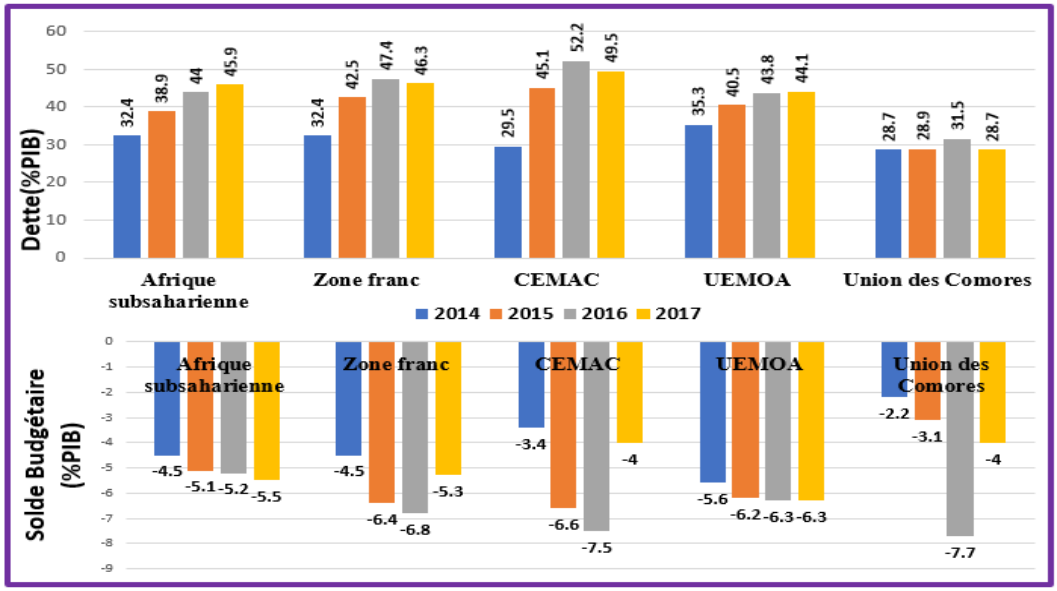

Fig. 1. Fiscal Balance and Public Debt in the Franc Zone between 2014 and 2017.
Source : Authors, using data from Banque de France, 2018

It shows that the CEMAC zone is the most indebted sub-region in the franc zone since 2015, probably due to the drop in oil prices in 2014. Even if the debt trend is increasing for all sub-regions between 2014 and 2016, there will be a marginal decline in external debt in 2017 in the franc zone, which is not the case in sub-Saharan Africa in general and in *WAEMU* in particular. This observation makes it possible to attribute this decrease in external debt in 2017 to the recovery of oil prices in 2016, after their decline in 2014.

With regard to budget balances, we note that in general, public debt increases when the budget deficit is large, with the exception of the Union of the Comoros, which registered the record deficit for the period at -7.7% of GDP, without however being heavily indebted. We also note that both the budget deficit of the WAEMU zone and that of Sub-Saharan Africa are on an increasing trend, almost at the

same pace as their debt level since 2014. In addition, WAEMU recorded the largest average budget deficit of the period, but it fluctuates little compared to that of other monetary unions in the franc zone. It therefore seems to have the most controlled deficit of the period.

4.1.2. Relationship between external debt and industrialization

a) Trends per country, of the external debt, investments and industrialization

Figure 2 shows the trends in the industrialization of foreign debt and investment by country over the period 1996-2017. The variables have been normalized to allow a better representation.

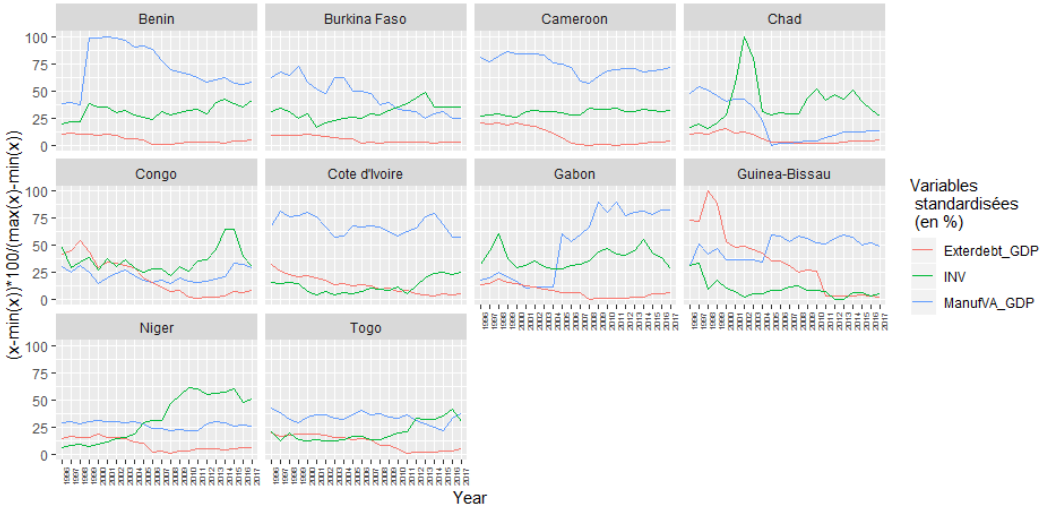

Fig. 2. Evolution per country of debt, investment and industrialization between 1996 and 2017.
Source : Authors, using data from the World Bank, 2019

This figure shows that it is not only the debt that is growing after the crisis and the completion point of the HIPC initiative. There has also been strong growth in the manufacturing sector and investment for all countries. However, while investments are declining for some countries like Gabon, Congo, Chad and Bukina Faso, the manufacturing sector is experiencing a new and growing dynamic after the 2014 crisis for all countries. This observation can be made either due to the fact that investments affect production with a time lag, or due to the fact that a large share of manufacturing output comes from the informal sector and small investors.

b) Non-linearity of the relationship between external debt and industrialization

The observation of the point clouds in Figure 3 [Point clouds on graphs per country have been adjusted by Loess regression with confidence intervals of à 95% for the related curves.] shows that for most of the countries in the sample, the relationship between external debt and industrialization is not linear; it also makes it possible to classify the countries into two groups: Burkina Faso, Guinea-Bissau, Benin and Congo, which have a declining global dynamic (more dots in this dynamic); for the rest of the countries, Togo, which seems to be indifferent, the dynamic is the opposite. For countries with a declining trend, on average over the period under consideration, as a country contracts additional debt, its manufacturing sector takes a hit. It is therefore a kind of crowding out effect on the manufacturing sector.

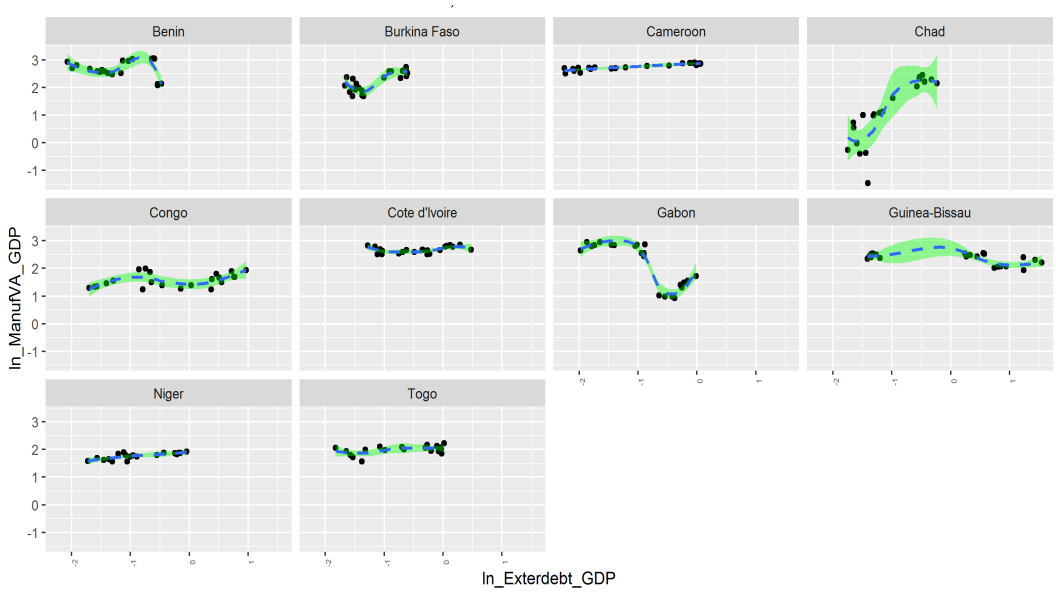

Fig. 3. Trend per country in the relationship between external debt and industrialization in the AFZ. **Source** : Authors, using data from the World Bank, 2019

We can also note that countries with a declining dynamic are also the most industrialized. However, this does not predict an overall negative impact of foreign debt on industrialization in the Franc Zone. For taking into account the specific effects of each country can lead to an overall positive impact of foreign debt on industrialization in the zone, all other things being equal.

Table 1 shows that most of the countries with the highest level of debt over the last five years before 2018 also have a better developed manufacturing sector. In CEMAC, the country with the highest manufacturing value added over the period

is Gabon (17.62% of the GDP). It occupies the second position in terms of debt in 2017 (41.4% of the GDP). In the WAEMU, on the other hand, Côte d'Ivoire with an estimated debt of 13432867414 USD (i.e. a ratio of 35.3% of the GDP), is the most indebted in value terms and has the highest manufacturing value added in relation to GDP over 5 years. However, some countries such as Congo, Niger, Chad and Burkina Faso have very low and almost stable industrialization over the period and relatively high debt. Congo is the least solvent with a debt/GDP ratio (51.2%) that is close to the 70% threshold allowed in CEMAC.

Year	**2013**		**2014**		**2015**	
Country	ManufVA	DEBT	ManufVA	DEBT	ManufVA	DEBT
Congo	4.3	24.49	4.74	27.53	7.33	47.47
Gabon	17.16	24.58	17.39	23.42	16.69	35.18
Niger	6.66	32.83	6.3	29.95	5.74	36.75
Côte d'Ivoire	16.2	31.51	16.85	27.72	14.73	34.33
Togo	6.05	20.74	5.57	21.59	4.82	25.23
Chad	2.72	22.59	2.69	26.95	2.78	27.16
Benin	12.92	21.88	13.18	20.98	12.19	26.33
Cameroon	14.99	15.99	14.42	16.48	14.66	23.46
Burkina Faso	5.35	21.47	6.27	20.54	6.62	25.16
Guinea-Bissau	12.68	26.53	12.38	25.76	10.7	30.05
Note	DEBT= Share of the external debt stock in the GDP; ManufVA= Share of the manufacturing added value in the GDP					

Table 1. Ranking of countries according to their external debt and industrialization levels in relation to GDP. **Source** : Authors, using data from the World Bank, 2019

Year	**2016**		**2017**	
Country	ManufVA	DEBT	ManufVA	DEBT
Congo	7.13	42.39	6.52	51.2
Gabon	17.46	36.22	17.62	41.4
Niger	5.94	38.35	5.71	40.93
Côte d'Ivoire	12.37	32.68	12.31	35.3
Togo	7.33	26.64	8.14	34.23
Chad	2.96	29.84	3.06	31.46
Benin	11.87	27.01	12.3	31.33
Cameroon	14.86	25.09	15.12	29.77
Burkina Faso	5.36	25.89	5.49	25.31
Guinea-Bissau	11.33	25.04	10.5	24.38

Table 2. Continuation of Table 2

4.2. Unit root test

Table 6 in the appendix presents the results of the unit root tests and the results of the individual dependence test in the last column. We choose the threshold of 5% for the interpretation of the results of any statistical test on this paper. The last column of this table shows that there is no individual dependency for the variables : GE, Corrupt, ln_Manufva_GDP, ln_Gov_GDP, ln_Fdi_GDP, ln_PrivInv,

ln_teleponesubsc and ln_GDPpercapt. At the end of this test, we can then consider the most appropriate LLC test for these variables. The results of the unit root test in general both for IPS and LLC show that all variables except the proportion of workers aged between 15 to 64, are stationary. For the latter variable, the LLC test shows that it could be in case of low individual dependency. However, its differentiated variable is stationary regardless of the test. Thus, in our analyses, we will also see if this variable is more relevant in terms of level.

4.3. Results analysis

4.3.1. Choice of the best transition variable and the number of transitions (m)

a) Choice of the best transition variable

For our modeling with a PSTR model, we chose the ratio of the stock of external debt to GDP as a transition variable. In order to reassure ourselves that this variable is the best transition variable among the probable transition variables, we have chosen 3 probable transition variables from the literature review :

1. **The quality of institutions :** Nounamo(2019), using a PSTR model, shows the role of institutions as a channel through which external debt affects growth;
2. **The debt/GDP ratio** : this variable was used by Oumou(2016) as a channel that could explain the threshold effect of public debt on economic growth in the WAEMU;
3. **Time transformed into a continuous variable (t/T)** : as presented in the literature of the PSTR model, this variable is a natural candidate as a transition variable, given that no economy remains stable over a long period.

The tests of homogeneity (linearity) considering these three variables allow us to observe that all three lead to the rejection (with values $pvalues < 10^{-6}$) of the hypothesis of homogeneity, which means that the PSTR model can be performed with each of them. As recommended by the literature on this model, to decide which one to choose, we take the one that most strongly rejects the hypothesis of homogeneity. Taking corruption as transition variable is the best, followed by external debt. If we instead take the quality of governance, it is the debt/GDP ratio that is the best transition variable. Given our objectives and the fact that quality of governance is more correlated with industrialization than corruption, we use debt as a percentage of GDP as a transition variable.

b) Choice of the number of transitions (m)

We have retained the number that most strongly rejects the hypothesis of linearity (m=1), all values being much lower than 5%.

4.3.2. Post-estimation tests and modeling results

a) Parameter constancy test

The LM_x and LM_F tests of parameter constancy suggest the hypothesis of parameter non-constancy, given that their values are less than 5%. However, having inspected the residuals for each model, we found that they have almost exactly the same distribution shape as inspected, with extreme values that are minima, corresponding to Chad for the years 2010, 2012 and 2013. We therefore chose to carry out two non-parametric tests: bootstrap test and bootstrap test per group (country). These two tests allow us to conclude that the parameters of the two models are constant over time (values greater than 10%, 5% threshold).

b) Absence of additional non-linearity test

Taking into account the effect of the extreme values which influence the parametric tests, we also performed the two previous nonparametric tests for the hypothesis of additional non-linearity, which allowed us to conclude that there is no additional non-linearity. Note that if we apply the procedure described at the end of the theory (3.2.4) on this model by choosing $\tau = 0.001$ and a threshold of $\tau\alpha = 0.0005$, we would end up with the same conclusions.

c) Normality test

Figures 4 below show the distribution of the model's residuals. The extreme points above can be seen in these figures.

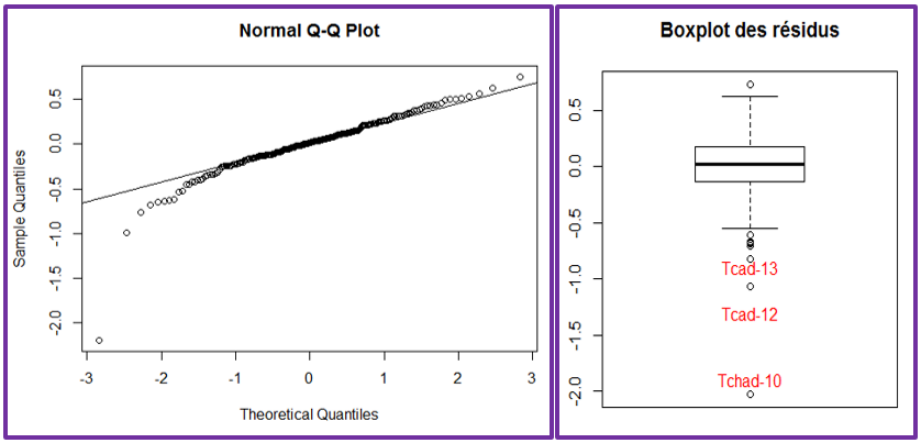

Fig. 4. Analysis of the Normality of Residuals.
Source : Authors, using data from the World Bank, 2019s

The non-parametric tests of Wilcoxon and Kolmogorove comparing the distribution of the residuals with a normal distribution of same size and same standard deviation with a null mean allow to conclude at the 5% threshold that the residuals of the models are normal (values larger than 5%, the null hypothesis being the equality of the distributions).

d) Choice of the threshold

Since the estimation of the parameters of the transition function is iterative for each value of the ratio of the stock of external debt to GDP, we have chosen to take as a threshold the first value at which the sign of the logarithm of the stock of external debt external debt (which is one of the explanatory variables) changes for a significant coefficient at the 5% threshold. Fig 5 presents the relative values of this variable for each value of the debt/GDP ratio.

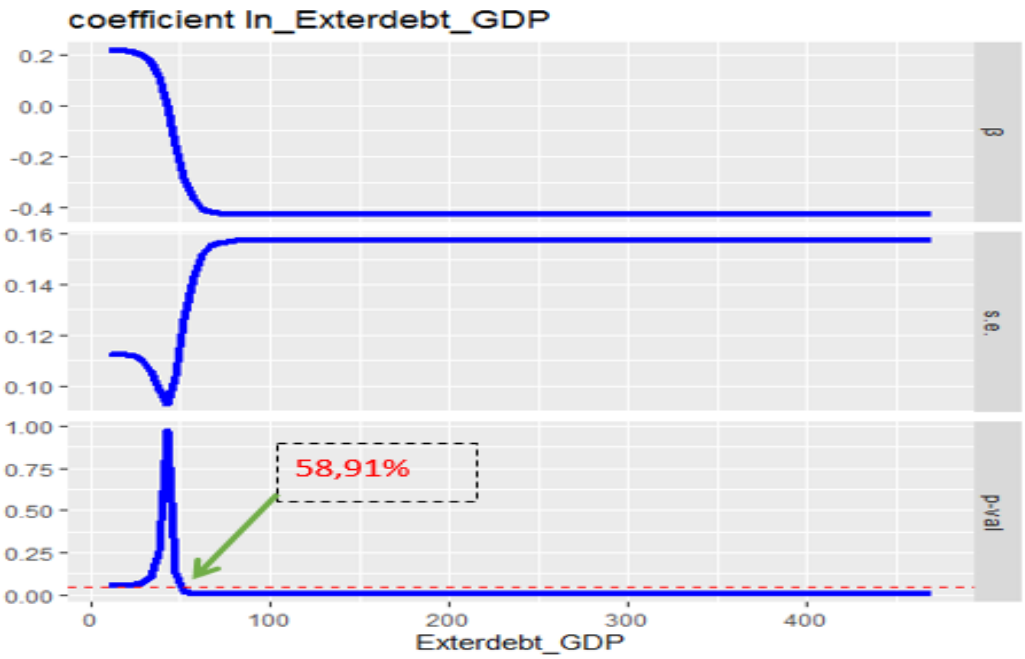

Fig. 5. Choice of the threshold.
Source : Authors, using data from the World Bank, 2019

This procedure allowed us to choose the threshold of 58.91%, whether we use the control of corruption or the quality of governance as the quality variable of institutions.

e) Interpretation of results

Analysis in presence of non-linearity. Table 3 presents the results of our estimates using a PSTR model. This table shows that, overall, the signs of the other variables in control are the same, regardless of the variable used as a proxy for the quality of the institutions. However, the main difference is related to the fact that the population is not significant in the first case and for the second regime, whereas it is in the second case. It can also be noted that taking into account the quality of governance improves the significance of foreign debt, with a value of 0.057 against 0.089 for corruption. In the end, we use the model with the corruption variable from control for the interpretation of the effect of the other control variables, apart from the quality of governance.

Table 3. Results of estimates. **Source** : Authors, using data from the World Bank, 2019

Variable	**Model with GE coeff(t-stat)^{signif}**			**Model with corrupt coeff(t-stat)^{signif}**		
	regime1	**non linear term**	**regime 2**	**regime 1**	**non linear term**	**regime 2**
ln_Exterdebt_GDP	0.209 (2.176)*	−0.624 (−4.344)***	−0.414 (−3.693)***	0.214 (1.899)*	−0.639 (−3.345)***	−0.425 (−2.703)**
ln_domcredit_GDP	0.169 (3.085)**	0.029 (0.383)	0.198 (3.322)***	0.112 (1.865)*	0.141 (2.381)**	0.253 (3.898)***
ln_FDI_GDP	0.01 (3.133)**			0.012 (3.01)**		
ln_Population	−0.777 (−2.367)**	0.163 (4.327)***	−0.614 (−1.814)	−0.773 (−3.332)***	0.162 (3.061)**	−0.611 (−2.597)**
HC	0.277 (2.144)*	−0.44 (−1.957)*	−0.163 (−1.043)	0.267 (1.915)*	−0.43 (−1.679)	−0.163 (−0.951)
GE	0.997 (3.036)**	−0.964 (−4.311)***	0.033 (0.216)			
Corrupt				0.807 (2.189)*	−0.902 (−2.753)**	−0.095 (−0.548)
teleponesubsc	0.04 (0.867)	−0.439 (−3.736)***	−0.399 (−4.162)***	0.138 (1.566)	−0.546 (−3.319)***	−0.408 (−4.33)***
gamma	0.226 (3.171)**	**Normality**		0.212 (1.926)*	**Normality**	
c_1	46.198 (7.304)***	**Stat**	**Pvalue**	46.177 (4.646)***	**Stat**	**Pvalue**
sigma	0.309	24833	0.635	0.303	24280	0.953

"signif" reflects the level of importance: "***"1%, "**"5%, "*"10%, ""$>$ 10%

External debt : Tableau 3 shows that external debt has a positive and insignificant effect on industrialization in a moderately indebted situation (regime 1). Thus, in this regime, external debt, if significant, would favor industrialization. On the other hand, in a situation of excessive indebtedness (debt $> 58.91\%$ of the GDP), an increase in the debt/GDP ratio of 1% would cause a contraction of industrial activity of 0.43%. It can therefore be seen that in the case of excessive indebtedness, the negative effects are stronger than the potential benefits of the external debt on the manufacturing sector in a situation of sustainable debt (according to the debt criterion $< 58.91\%$ of GDP defined above).

Domestic credit: this variable, although significant at the threshold of 10% in regime 1, shows that its benefits on the manufacturing sector are greater in the case of excessive debt: a 1% growth in this variable causes an increase in industrialization of 0.11% if one is in a situation of debt that is sustainable for industrialization, and of 0.25% in the case of over-indebtedness. This reflects the tightening of external financing conditions during periods of over-indebtedness, which pushes investors to look for domestic financing. As the informal sector and the SME sector are predominant in the economies of the franc zone, they finance their activities more through local banks, hence the positive sign regardless of the debt situation. The classical hypothesis that in a situation of indebtedness agents can save to prevent a future tax is also a plausible explanation.

IDE/FDI in relation to GDP: FDI is generally investment brought in by foreigners in order to make a profit. In terms of capital inflows, it is a part of external financing independent of the level of debt, reason why our statistical analyses have suggested that we should not apply a non-linearity effect to external debt to this variable. Thus, a 1% increase in FDI leads to a marginal growth of 0.01% in the share of the manufacturing sector.

Population: regardless of the regime, population is a brake on industrialization. Indeed, a 1% demographic growth causes a reduction in industrialization of 0.77% in the first regime and 0.61% in the second. The contribution of an excessive debt on the effect of this variable is therefore positive and is worth 0.162%. This can be explained by the commissions, work groups for projects with external financing and work on public investment projects that increase the average income of consumers in the AFZ and promote the demand for manufacturing goods.

Human Capital (HC). In a situation of medium-term indebtedness, human capital makes a positive contribution to industrialization. This is in line with Lucas' growth model. However, this variable is significant at the threshold of 10% in this first regime. But a high level of indebtedness alters the effect of this variable on industrialization.

Quality of Governance (GE). the model with this variable as the quality of institutions shows that improving the quality of governance by one point increases the share of manufacturing value added in GDP by almost 1% (0.997) in the case of moderate debt. This is the most significant variable of the model in this regime. However, in the case of high debt, this effect is reduced by 0.96%, thus leading this variable to a regime where it no longer significantly influences industrialization.

Level of corruption control (Corrupt). The effect of this variable on industrialization is similar to the previous one. We note a 0.8% growth in industrialization following a unit growth in the latter in a situation of moderate debt. On the other hand, high debt leads to a deterioration of the effect of this variable on industrialization of 0.9%, thus leading the level of control corruption in the second

Variable	Estimatefor the period 1996-2006			Estimatefor the period 2007-2017		
	FE Model	Hetero GLS Model	SUR Model	FE Model	GLS Model	SUR Model
ln_ManufVA_GDP	Coef (t-stat)	Coef (Z-stat)	Coef (Z-stat)	Coef (t-stat)	Coef (Z-stat)	Coef (Z-stat)
ln_Exterdebt_GDP	0.3(1.58)	0.365(4.9)***	0.51(4.66)***	0.082(1.71)*	0.137(1.59)	0.054(0.94)
ln_domcredit_GDP	0.197(1.86)*			0.201(5.48)***	0.225(5.16)***	0.218(8.70)**
ln_FDI_GDP	0.022(2.89)***			0(0.06)		
Internet_share	0.392(5.03)***	0.131(2.37)**	0.215(3.09)***	-0.011(-2.89)***		
ln_Population	-2.65(-3.39)***	0.416(9.26)***	0.475(6.3)***	0.252(0.71)	-0.406(-8.18)***	-0.402(16.36)**
Inflation	-0.005(-0.87)			0.008(1.39)		
Corrupt	0.128(0.44)	0.375(4)***	0.616(4.02)***	0.427(2.44)**	0.662(5.01)***	0.475(4.66)**
Teleponesubsc	0.55(2.18)**			0.042(1.08)	0.42(9.68)***	0.345(9.32)**
_cons	41.054(3.26)***	-5.696(-6.18)***	-7.095(-4.65)***	-2.306(-0.41)	7.672(8.47)***	7.828(16.65)**
sigma_u	3.339			0.798		
sigma_e	0.401			0.186		
rho	0.986			0.948		
corr(u_i,Xb)	-0.987			-0.448		
(N,T)	(10,11)	(10,11)	(10,11)	(10,11)	(10,11)	(10,11)
R2 within	0.362			0.4187		
R2 between	0.28			0.0074		
R2 overall	0.119			0.0207		
R2 SUR			0.332			0.634
Pvalue (u_i=0)	0			0		
Asterisks indicate the significance level : "***" 1%, "**"5%, "*"10%, ""> 10%						

Fig. 6. Results of the estimates in two sub-periods : 1996-2006, 2007-2017. **Source** : Authors, using data from the World Bank, 2019

regime to have a negative and insignificant effect on industrialization.

The proportion of subscribers to mobile telephony (tel. subscribers): In a situation of moderate indebtedness, this variable does not influence industrialization, but in the case of high indebtedness, it becomes a brake on industrialization. Thus, an increase of one unit of this variable causes a 0.4% deterioration of industrialization.

Analysis in two sub-periods : 1996-2006, 2007-2017. In order to understand the situation of the franc zone countries after the end of the Heavily Indebted Poor Countries (HIPC) initiative and during the recovery period and the strategic documents on growth and employment, we have carried out an analysis of the period after the devaluation of the CFA franc 1996-2006 and another on the period 2007-2017, after the *HIPC* initiative. The latter period was marked by debt remission. The results of the estimates are presented in Figure 6 below.

It was not and could not be possible to carry out non-linearity tests, given the small sample size, on the time dimension for the two periods (pvalue=$0 < 5\%$). Moreover, the estimation by this model, allows to observe that there is auto correlation of errors (Wooldridge test with absence of auto-correlation of first order panel, gives a *pvalue* of $0.002 < 5\%$) for the period 1996-2006, while there is the problem of auto-correlation and heteroskedasticity (Wald's test performed, under

the null hypothesis of equal variances : $pvalue = 0 < 5\%$) for the period 2007-2017.

The estimation by the Generalized least squares (GLS) method or by the Seemingly Unrelated Regression (SUR) method of Zellner (1962) have been used to correct these problems, and the third and fourth columns present the results of these two estimates for the period 1996-2006. The same estimates made for the period 2007-2017 give very similar results.

For the **period 1996-2006**, given that the results for the two methods mentioned above have the sign with the lower coefficients obtained by the GLS method (with specification of heteroskedasticity), we will retain those obtained by the SUR method for interpretation. This is justified by the fact that it is more efficient in the presence of auto-correlation and that the variable relative to the share of individuals using the Internet is more significant for the latter.

External debt : an increase in the *debt/PIB* ratio of 1% leads to an increase in the share of manufacturing value added of 0.51%. The external debt therefore has a positive and significant effect on industrialization during this period.

Proportion of the population using the internet : An increase in the share of individuals using the internet by one per thousand leads to an increase in industrialization of 0.21%.

Population A 1% increase in population increases the level of industrialization by 0.48%.

Corruption control However, a 1% increase in the level of corruption increases the level of industrialization by 0.61%.

It should also be noted that without the contribution of an industrialization factor, on average, the growth rate of manufacturing value added in relation to GDP is negative.

For the **period 2007-2017**, the main difference with the above is the insignificance of the debt. Also, we note: (i) a negative effect of population on industrialization; (ii) that the proportion of individuals having subscribed to mobile telephone services per 100 inhabitants is more appropriate (significant) for the model than the proportion of individuals using the Internet; (iii) Credit to the economy is also a better source of financing for industrialization after the end of the HIPC initiative. The following interpretation is valid for the results of the estimation after correcting for the heteroskedasticity by the method of the generalized least squares.

Domestic credit : an increase in the credit rate in the GDP of 1%, increases the level of industrialization by 0.22%.

Population. A 1% increase in population reduces the level of industrialization by 0.40%. This negative sign can be found related to the higher consumption of imported products, to the detriment of local products. This is also explained by the fact that responses to hunger strikes and civil wars are usually based on consumption subsidies (or humanitarian aid) and on imported products.

Corruption control. A level of corruption control increasing by 1% increases the level of industrialization by 0.66%

Proportion of individuals having subscribed to mobile telephony : a 1% increase in the proportion of individuals using mobile telephony leads to a 0.42% increase in industrialization

Without the contribution of an industrialization factor, the growth rate of manufacturing value added in relation to GDP is 7.7% on average, which shows the dynamics of the manufacturing sector is growing after 2006, although the debt is not for the most part. The insignificance of the debt is justified by at least 3 reasons: (i) 2006 marks the beginning of debt remission [due to the end of the HIPC initiative] which began in the best developed countries of the franc zone (Cameroon and Côte d'Ivoire, etc.); (ii) Several crises followed (over primes, oil shock, etc.), thus tightening the foreign capital market; (iii) With Information and Communication Technologies (ICT), several StartUp companies are emerging and using social networks as their main means of advertising, encouraged by numerous initiatives to facilitate access to financing for SMEs..

Overall, these results make us understand that the debt had a greater effect on industrialization after the devaluation of the CFA franc. However, industrialization before the HIPC initiative had weaker dynamics than after, despite the crises that occurred in most franc zone countries after 2006. It should be noted, however, that for both periods, increasing the level of corruption control is beneficial for industrialization. The advent of *ICT*'s and in particular cell phones would also have had a considerable effect on industrialization over time.

It should be noted, however, that the results of non-linear estimates have shown that corruption and the level of governance become problems as soon as the level of indebtedness becomes high. These variables may contribute to making debt a brake on industrialization. In fact, the crisis that accompanies over-indebtedness pushes public officials and corruption control authorities to become catalysts of this phenomenon, and their discomfort due to the crisis can also impact the quality of governance.

5. Conclusion and recommendations

The aim of this article was to assess the impact of external debt on industrialization in the African franc zone and in the presence of non-linearity. To

do so, we began by presenting two major currents of thought that are divided with regard to the impact of external debt on industrialization. While the Keynesians are in favor of debt because they think it favors investment thanks to the multiplier effect and to the financing of the budget deficit, the classics have a contrary opinion. They consider external debt as a fatal tax for future generations, which in the best case is anticipated by the agents. The latter will therefore prefer to save in order to protect themselves from the external debt and consequently reduce their consumption. A synthesis of these two theories, presented by Barro (1974), Barro (1989), Barro& Sala-i-Martin (2004) under the Ricardian concept of equivalence, shows that external debt would have no effect on industrialization. It should also be noted that the different industrialization policies that have been pursued so far have not had the expected results, since these different models did not take into account the global context and the reality of each African country. With regard to the literature on the determinants of industrialization, the quality of institutions can also be a factor of defect in quality. This observation is confirmed by the IMF (2019)(P.18). The latter finds that corruption is the main constraint on business activity in North Africa and the Middle East. Following Oumou(2016), who worked on the case of growth, we found a threshold of 58.91% for the *external/GDP* ratio, above which external debt negatively influences industrialization, while below this threshold it does not. Our results are consistent with the assumptions of the neoclassical school, in case of excessive debt.

Our economic policy recommendations concern two aspects: the strategic aspect and the financing aspect of the strategy.

From a strategic point of view, a phase of promotion of industrialization based on industrializing industries that starts from a collection of the current potential in full expansion followed by a subsidy of the sectors with the most spillover effect on the others is necessary. After this phase will follow a phase that consists in encouraging consumption. This phase is therefore a kind of hybrid ISI, where the state allows foreign companies to enter, not with the aim of killing local entrepreneurship, but with the aim of boosting it. The choice of the type of business to be prioritized is therefore crucial and depends on the observation of the need according to the country. A final phase, which consists of practicing industrialization through export promotion based on the comparative advantages of countries in relation to their neighbors and the rest of the world, will allow them to integrate into the global values chain.

Regarding the financing aspect which is our main concern in this paper, we have noticed that Islamic finance products are less expensive. However, they are limited to financing projects that are in accordance with the principles of the Koran, some projects (Pork farming, creation of breweries, etc.) cannot obtain financing through this means. However, there are other alternatives, such as participatory financing, which consists of having a donor or an individual finance all or part of a project and share its operation with that donor or individual and share its

operation with the latter for a certain period of time (public-private partnership, private partnership, etc.). The governments of Franc zone countries can encourage their diaspora to form groups to undertake business in their respective countries. One can also attract FDI by promoting those that allow the smooth implementation of the country's industrialization strategy (For example, more companies to transform raw material in intermediate consumption for local companies, looking at the cost of the capital of such companies). The latter recommendations will be very useful for Congo, whose debt level is unsustainable from the industrialization point of view (51.2% of GDP).

In short, policies to open up the industrial sector and promote technology transfer must be a priority. For the proper implementation of our recommendations, strong institutions must be put in place, and the leaders of the AFZ countries and their citizens must have a sense of responsibility and civic-mindedness.

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Appendix

Table 4. Presentation of variables

Variable	Description	Transformation
ManufVA_GDP	Manufacrturing Added Value as a percentage of GDP	natural logarithm
GE	Governance Quality Index	none
Exterdebt_GDP	Stock of external debt as a percentage of GDP	natural logarithm
GOV_GDP	Public expenditure as a percentage of GDP	natural logarithm
domcredit_GDP	Domestic credit to the economy as a percentage of GDP	natural logarithm
FDI_GDP	IDE as a percentage of the GDP	natural logarithm
domcredit_toprivate_GDP	Domestic credit to the private sector as a percentage of the GDP	natural logarithm
Openess	Degree of openess [(exportations+importations)/2*GDP	natural logarithm
INV	Investments (FBCF)	natural logarithm
Priv_INV	Private investments	natural logarithm
Internet_share	Part of the population using internet for every 1000 inhabitants	natural logarithm
Population	Population of a country	natural logarithm
Inflation	Inflation index measured by Consumption price index	none
labor_15_64	Part of workers between 15 and 64 years	none
HC	Human capital	none
Corrupt	Corruption control index	natural logarithm
teleponesubsc	Part of the population having souscribed to mobile telephony for every 100 habitants	none
PercaptGDP	GDP per inhabitants	natural logarithm

Source: Authors, using data from the World Bank, 2019

Variable	Dimension	Mean	SD	Min	Max	Variable	Mean	SD	Min	Max
ManufVA_GDP	overall	9.97	5.05	0.23	21.20	**Corrupt**	-0.89	0.36	-1.56	0.11
	between		4.18	4.73	15.64			0.34	-1.34	-0.20
	within		3.12	1.48	18.09			0.16	-1.34	-0.36
Exterdebt_GDP	overall	66.92	67.73	10.55	470.02	**GOV_GDP**	0.13	0.04	0.04	0.26
	between		43.08	34.24	173.83			0.04	0.06	0.22
	within		53.94	-82.53	363.12			0.02	0.08	0.23
domcredit_toprivate_GDP	overall	12.22	7.67	0.40	41.80	**FDI_GDP**	3.52	6.47	-8.59	50.02
	between		5.69	4.72	22.82			2.98	1.13	10.34
	within		5.45	0.87	31.20			5.82	-11.67	43.37
domcredit_GDP	overall	15.73	9.31	0.81	48.42	**INV**	0.21	0.08	0.06	0.60
	between		6.29	10.10	28.36			0.06	0.11	0.27
	within		7.13	3.68	41.53			0.06	0.06	0.54
Openess	overall	5.24 E+19	8.97E+19	1907E+16	4.69E+20	**Priv_INV**	14.05	7.03	1.46	49.59
	between		6.89E+19	1958E+17	2.10E+20			5.30	3.46	20.19
	within		6.12E+19	-9.14E+20	3.12E+20			4.91	0.05	44.43
Inflation	overall	3.00	5.49	-8.97	50.73	**Population**	9.92 E+06	6.76E+06	1.11E+06	2.46E+07
	between		1.44	1.77	6.86			6.73E+06	1.42E+06	1.92E+07
	within		5.32	-9.33	46.87			2.19E+06	4.85E+06	1.66E+07
Internet_share	overall	4.54	8.66	0.00	50.32	**HC**	1.68	0.42	1.05	2.78
	between		3.96	1.15	14.16			0.36	1.14	2.36
	within		7.80	-9.62	40.70			0.23	1.01	2.70
telepone subsc	overall	0.96	0.92	0.00	5.20	**labor_15_64**	71.67	9.11	47.86	83.36
	between		0.69	0.19	2.19			9.32	50.36	80.74
	within		0.64	-0.46	4.23			2.10	65.37	79.32

Table 5. Characteristics of studied variables. **Source** : Authors, using data from the World Bank, 2019

Variable	IPS	LLC	Pvalue du CD test
GE	I(0)**	I(0)**	0.561
Corrupt	I(0)*	I(0) *	0.714
HC	I(0) ***	I(0) ***	0
Inflation	I(0) ***	I(0) ***	0
ln_labor_15_64	I(1)	I(0) **	0.02
D.ln_labor_15_64	I(0)**	I(0) **	0.25
ln_Manufva_GDP	I(0) *	I(0) ***	0.684
ln_Exterdebt_GDP	I(0) ***	I(0) ***	0
ln_GovGDP	I(0) ***	I(0) ***	0.926
ln_domcredit_GDP	I(0)*	I(0) *	0
lnFDI_GDP	I(0) ***	I(0) ***	0.287
lndomcredit_toprivate_GDP	I(0)**	I(0) **	0
ln_Openess	I(0) ***	I(0) ***	0
ln_INV	I(0) *	I(0) **	0
ln_PrivInv	I(0) **	I(0) ***	0.833
ln_Population	I(0) ***	I(0) ***	0
ln_debt2	I(0)*	I(0)*	0
ln_Internet_share	I(0) ***	I(0) ***	0
ln_teleponesubsc	I(0) ***	I(0) ***	0.06
ln_GDPpercapt	I(0) ***	I(0) ***	0.065
Significance level : ""> 5%; "*"5%; "**"1%; "***"0.1%.			

Table 6. Unit root test. Source : Authors, using data from the World Bank, 2019

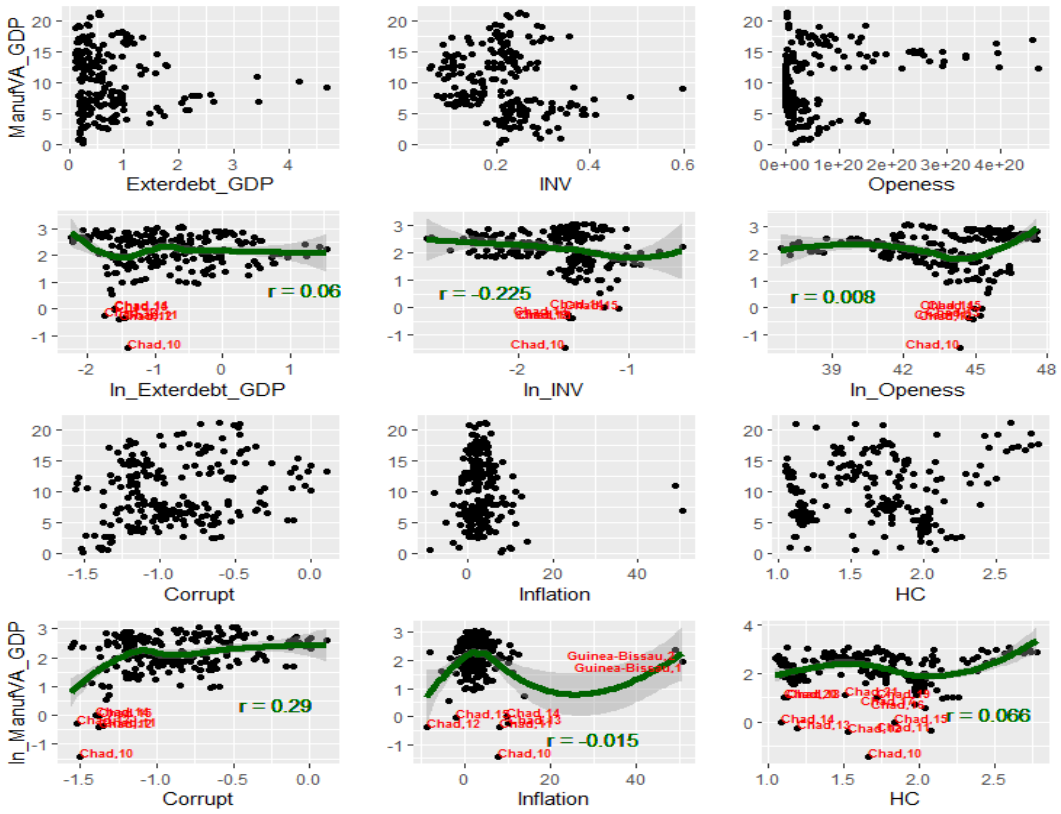

Fig. 7. Transformation of explanatory variables and relationship with industrialisation. **Source**. Authors, using data from the World Bank, 2019

Table 7. Estimations after 2 lever points leviers by the quantiles ordres of 1% and 1.5% of the manufacturing added value ratio to the GDP. **Source** : Authors, using data from the World Bank, 2019

Variable	**Model with GE coeff(t-stat)^{signif}**			**Model with corrupt coeff(t-stat)^{signif}**		
	regime1		**regime2**	**regime1**	**non linear term**	**regime2**
ln_Exterdebt_GDP	0.225 (2.23)*	−0.637 (−4.254)***	−0.412 (−3.695)***	0.233 (1.821)	−0.636 (−3.246)**	−0.403 (−2.814)**
ln_domcredit_GDP	0.17 (2.902)**	0.024 (0.31)	0.194 (3.341)***	0.116 (1.73)	0.13 (2.06)*	0.245 (4.023)***
ln_FDI_GDP	0.009 (3.059)**			0.011 (3.072)**		
ln_Population	−0.864 (−3.154)**	0.163 (4.307)***	−0.701 (−2.528)**	0.161 (3.013)**	0.162 (3.061)**	−0.686 (−3.261)**
HC	0.287 (2.262)*	−0.443 (−1.974)*	−0.156 (−1.051)	−0.418 (−1.648)	−0.43 (−1.679)	−0.142 (−0.909)
GE	0.982 (3.024)**	−0.971 (−4.136)***	0.011 (0.078)			
Corrupt				0.724 (2.395)**	−0.839 (−2.99)**	−0.115 (−0.68)
teleponesubsc	0.036 (0.846)	−0.425 (−3.794)***	−0.39 (−4.152)***	0.138 (1.566)	−0.536 (−3.523)***	−0.404 (−4.343)***
gamma	0.226 (3.601)***	**Normality**		0.215 (2.26)*	**Normality**	
c_1	46.202 (7.212)***	**Stat**	**Pvalue**	46.18 (4.91)***	**Stat**	**Pvalue**
sigma	0.26	24033	0.835	0.303	23901	0.983

"signif" indicates the level of significance: "***"1%, "**"5%, "*"10%, ""> 10%