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Posted Date: 8 May 2026

doi: 10.20944/preprints202605.0528.v1

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Article

# From Growth Pole to Peripheral Disparities: The Nkok SEZ in Gabon, Socio-Economic Spillovers, and the SEMD Operational Framework for Balanced Territorial Development

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## Abstract

Special Economic Zones (SEZs) are widely promoted as catalysts for industrialization and export growth in developing countries, yet their capacity to generate sustainable and inclusive regional development remains debated, particularly in sub-Saharan Africa. This study investigates the impact of the Nkok SEZ in Gabon on the forestry sector—a novel case study—by analyzing the resulting economic and spatial disparities between the SEZ (homogeneous space) and its periphery (heterogeneous space). Combining robust econometric methods (Bias-Corrected Fixed Effects, OLS) and principal component analysis (PCA) on time-series data (2014–2022), we show that while the SEZ has significantly boosted export revenues (84%–97% growth) and industrial production through agglomeration and scale economies, these benefits remain largely concentrated. The periphery experiences weaker growth, reinforcing center-periphery dependencies and extractive specialization. Export revenues from the homogeneous space exhibit strong autoregressive effects (77%–94%) but limited macroeconomic diffusion (6%–25%), whereas the heterogeneous space shows lower autoregressive growth but a stronger historical influence on national aggregates, highlighting a structural polarization trap. To address these persistent imbalances, this paper introduces the SEMD model (Segmentation, Evaluation, and Multi-level Disparities Management). This operational framework proposes a six-fold territorial typology (from SEZs to informal circuits), hybrid quantitative-qualitative indicators, and proactive rebalancing mechanisms (vertical and horizontal channels) to institutionalize the diffusion of growth. The SEMD model offers a strategic tool for policymakers in the Global South to reconcile industrial performance with territorial cohesion, moving beyond the mere diagnosis of inequalities toward adaptive, real-time management of polarized development dynamics.

**Keywords:** special economic zones (SEZs); polarized growth; regional disparities; center-periphery model; forestry sector; Gabon; SEMD model; sub-Saharan Africa; unbalanced development; agglomeration effects

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## Introduction

Special Economic Zones (SEZ) have established themselves as a major lever for economic development in developing countries, promoting industrialization and export growth. Numerous studies have highlighted their impact on the spatio-temporal evolution of growth poles, thus underlining the need for emerging and industrialized countries to develop appropriate strategies for monitoring and anticipating the transformations under way (UNCTAD, 2019; Farole & Akinci, 2011; NESDC, 2022) [5,6,50]. However, least developed countries face difficulties in implementing such adaptation mechanisms due to the lack of specialized tools for strategic planning and performance monitoring. Furthermore, the establishment of the SEZ often generates regional imbalances,

requiring a thorough analysis of their dynamics and effects on local economies (Frick et al., 2019; Farole & Akinici, 2011) [6,49].

Econometric research on SEZ has explored their impact on regional economic development by mobilizing various methodologies, including panel models, the difference-in-differences technique (DiD), time series and matching by propensity score. For example, Wang (2013) [51] studied the effect of Chinese SEZ on exports using a DiD approach, while Aggarwal (2012) [52] used a panel model with Time-Generalized Estimation (MMA) to examine the Indian case. Farole (2011) [4] compared the performance of the SEZ in Africa and Asia, showing a more limited effectiveness on the African continent. On their impact on industrialization, Johansson and Nilsson (1997) [54] have revealed a positive relationship between investment in these areas and industrial growth in a panel of 40 developing countries. Zeng (2015) [53] compared the Chinese and African experiences through a DiD approach, highlighting a more pronounced transformation in China, while Alder, Shao and Zilibotti (2016) [55] demonstrated, using an endogenous growth model, the multiplier effect of SEZ reforms on China's industrial productivity and their role in convergence with advanced economies.

However, there has been little literature on the impact of SEZs on specific sectors, such as forestry. The case study of Gabon thus makes an original scientific contribution by analyzing the effects of the Nkok SEZ on this strategic sector. It proposes a segmentation of the macro-environment into two distinct spaces: a homogeneous space, corresponding to the SEZ, and a heterogeneous space, representing the areas outside the SEZ. This approach is based on the theory of growth poles by François Perroux (1955) in order to study the differentiated spatial dynamics generated by these special economic zones.

From a methodological point of view, this research mobilizes advanced econometric techniques adapted to short panels and time series, such as the "Fixed Effect-Bias-Corrected Estimation (Robust)" method and the Least Ordinary Squares (MCO) method robust. A Principal Component Analysis (PCA) is also applied to visualize the disparities between homogeneous and heterogeneous space. By focusing on the Gabonese forest sector, which has not yet been explored in studies on the SEZ, this research offers a new perspective on regional growth and socio-economic inequalities in Africa. The originality of this study lies in its specific theoretical and methodological approach. Contrary to international research which favors a global analysis of the effects of the SEZ on exports and the attractiveness of investments. This study takes a regional approach by modeling the unbalanced growth and spatial inequalities induced by these areas. Two main objectives are pursued:

1. To analyze empirically the influence of the Nkok SEZ on the forestry sector in Gabon and to compare regional disparities between homogeneous and heterogeneous spaces;
2. Explain the endogenous growth mechanisms and dynamics underlying the observed economic inequalities.

## Literature Review

### I. Theories of regional unbalanced growth

Theories of unbalanced regional growth seek to explain why some regions develop more rapidly than others, leading to economic disparities. Unlike approaches advocating balanced development, these theories consider the spatial and temporal evolution of imbalances as a dynamic element. François Perroux (1955) [1], developed the theory of growth poles, putting forward a model based on driving units exerting economic attraction and diffusion forces (Boudeville, JR, 1966) [2]. Myrdal (1957) [7] introduced circular cumulative causality, emphasizing that interactions between developed and lagging regions tend to increase regional inequalities through propagation and feedback effects. Williamson (1965) [8] proposed the "inverted U" theory, suggesting that regional disparities first increase with economic development before stabilizing and then decreasing (Kanbur, R., & Venables, AJ, 2005) [9]. Hirschman (1958) [11] advocates unbalanced growth by concentrating investments in certain strategic sectors to generate spillover effects (Hirschman, AO 1958) [11] (Todaro, MP, & Smith, SC, 2015) [12] (Ray, D., 1998) [13]. Friedmann (1966) [14]. Develops the core-periphery theory, explaining that central regions develop more quickly, leaving the peripheries in a state of increased

dependence. Finally, Krugman (1991) [15], with the New Geographical Economics, highlights the role of agglomeration economies and transport costs in accentuating regional imbalances. These theories have largely influenced regional development policies, although they are criticized regarding their ability to reduce inequalities in the long term.

## II. The impacts of SEZs in developing countries

Growth poles, have been widely adopted by developing countries as economic policy instruments to stimulate regional development. Their evolution over time reflects the transformations in approaches to economic development, influenced by economic theories and the global context. Ge, W. (1999). [3]. Farole, T. (2011). [4]. With globalization and the rise of global value chains between 1980 and 2000, these poles have gradually integrated special economic zones (SEZs) and free trade zones. This trend has been particularly evident in East Asia and China, where SEZs have been integrated into broader economic reforms, playing a crucial role in industrialization and economic opening. SEZs, as economic policy instruments, have evolved in line with global, regional and local dynamics, moving from an initial role in industrial reforms to a growing involvement in the digital and green economies.

Econometric research on the impact of Special Economic Zones (SEZs) in developing countries offers varied perspectives on their effectiveness and resulting policy recommendations. Regarding exports, Wang (2013) [51], using the difference-in-differences method applied to a panel of Chinese cities, found a 20–30% increase in exports in cities with SEZs. This study highlights their crucial role in integrating Chinese cities into global value chains, suggesting the need for policymakers to strengthen infrastructure and improve access to international markets. Aggarwal (2012) [52], using a panel model with fixed effects and GMM estimation, demonstrated that Indian SEZs have boosted exports, particularly in the manufacturing sector, by attracting foreign investment. Unlike China, where these zones have benefited from strong state support, the success of Indian SEZs relies more on a more liberal framework and targeted tax incentives, highlighting the importance of a favorable business climate to optimize their effectiveness. Comparing SEZs in Africa and Asia, Farole (2011) [4] highlighted the more limited impact of African SEZs on exports, due to a lack of suitable infrastructure and less attractive policies, which underlines the need for African governments to invest more to make these zones more competitive.

Concerning the impact of SEZs on industrial production, Johansson & Nilsson (1997) [54]. revealed, through a panel regression on 40 developing countries, that a 10% increase in investment in a SEZ leads to a 5% increase in industrial production, thus illustrating the importance of capital and infrastructure investments to maximize industrial growth and encourage sectoral diversification. Zeng (2015) [53], applying a DiD analysis, showed that Chinese SEZs have promoted structural industrial transformation and an upscaling of exports, while their impact in Africa remains more limited, due to a lack of integration into global value chains and industrial complementarities. It therefore appears necessary to strengthen the links between local companies and exporting industries to increase their efficiency. Finally, Alder, Shao & Zilibotti (2016) [55], through an endogenous growth model based on time series, highlighted the multiplier effect of SEZ reforms on industrial productivity in China, facilitating convergence with advanced economies. This study emphasizes the key role of innovation, training and technology transfer in optimizing the long-term benefits of SEZs.

## III. The impacts of SEZs Nkok in Gabon

Between 2014 and 2022, Gabon experienced strong growth in industrial revenues from the forestry sector, particularly concentrated around the Nkok Special Economic Zone (SEZ), created in 2011. According to Perroux's theory, this SEZ constitutes a "homogeneous" space capable of generating an economic force field that transforms the surrounding territories, described as "heterogeneous" spaces.

The analysis of the data (Figure 3 and Tables 4 and 5) highlights strong disparities between homogeneous and heterogeneous areas, both in terms of volumes produced and values exported, fully illustrating the phenomenon of economic polarization induced by the Nkok SEZ.

In the Nkok Special Economic Zone (SEZ), industrial production increased from 6,798 m<sup>3</sup> in 2014 to 608,000 m<sup>3</sup> in 2022, representing an almost hundredfold increase. Conversely, the heterogeneous area did not experience comparable growth, although in 2022 it still showed a higher overall volume. These differences illustrate a polarizing effect marked by the development of major infrastructure concentrated around the SEZ: ports, railways, and the immediate proximity of Libreville. This dynamic corresponds to the concept of "Big Push" developed by Rosenstein-Rodan (1943) [45], which stimulates polarizing effects and leads to an increase in export volume, as shown in Table 4.

In parallel, Myrdal's strategy (1957) [7], which recommends targeted interventions to exploit the potential of already developed regions, is reflected in the investments made in the SEZ. These investments have contributed to strong export growth, with the value increasing from USD 4 million in 2014 to USD 511 million in 2022 for the homogeneous area, thus exceeding the revenues of the heterogeneous area (USD 506 million). These results reflect an asymmetrical dynamic of industrialization and export specialization.

However, these rapid transformations also raise risks of spatial inequalities and "core-periphery" effects described by Friedman (1966) [14] and the potential negative effects mentioned by Myrdal (1957) [7]. Hence the need for careful strategic monitoring to maximize economic benefits while reducing these imbalances.

## II. Methodology

### I. Econometric methods used to study regional disparities associated with growth poles

Many econometric studies have examined the impact of Special Economic Zones (SEZ) on export growth and industrial development in developing countries. To assess these effects, different analytical methods were used, including panel models, difference-in-differences (DiD) techniques, time series and matching by propensity score (PSM).

Regarding the effect of SEZ on exports, Wang (2013) [51] conducted a study on Chinese municipalities between 1988 and 2007 using the difference-in-differences method (DiD), while Aggarwal (2012) [52] used a panel model with fixed effects and an estimation by the generalized moments method (GMM) to analyze the Indian case. Farole (2011) [4] compared the impact of SEZ in Africa and Asia using a quasi-experimental approach, highlighting more limited performance in Africa.

For industrial production, Johansson and Nilsson (1997) [54] studied a panel of 40 developing countries using a regression model, showing a positive relationship between investment in the SEZ and industrial growth. Zeng (2015) [53] adopted a difference-in-differences (DiD) approach to compare Chinese and African experiences, revealing a more marked transformation in China. Finally, Alder, Shao and Zilibotti (2016) [55] used a time-series-based endogenous growth model to demonstrate the multiplier effect of SEZ reforms on industrial productivity in China, contributing to faster convergence with advanced economies.

**Table 1.** Summary of Econometric Methods Used.

Method	Examples of studies	Goals
Differences-in-differences (DiD)	Wang (2013), Zeng (2015)	Compare exports/production between regions with and without SEZ
Panel model (GMM, fixed effects)	Aggarwal (2012), Johansson & Nilsson (1997)	Measure the long-term impact of the SEZ
Time series	Alder et al. (2016)	Analyzes the growth dynamics of the SEZ over several decades
International comparisons	Farole (2011)	Assess the performance of SEZ in Africa vs. Asia

### II. Approach for the case study of the Nkok SEZ in Gabon

From a methodological point of view, this study draws on the theory of unbalanced regional growth, in particular the theory of growth poles by François Perroux (1955), to segment the macroenvironment of the Gabonese forestry sector into two distinct spaces: a homogeneous space, corresponding to the SEZs, and a heterogeneous space, representing the areas located outside the SEZs. This spatial distinction, already theorized by Perroux and widely used in regional development, is mobilized here to model unbalanced endogenous and regional growth using econometric methods. The objective is to evaluate the positive effects on the macroenvironment and to highlight the spatial and socio-economic disparities, thus constituting an innovative approach in the analysis of the impact of SEZs on economic development. The study is based on two complementary approaches to analyze the influence of the Nkok SEZ on the Gabonese forestry sector and the underlying mechanisms. The first is an econometric approach using two types of non-parametric models. On the one hand, the "Fixed Effect-Bias-Corrected Estimation (Robust)" method, adapted to short panels, makes it possible to correct estimation biases related to temporal dimensions and to assess the impact of the variables of the SEZ (homogeneous space) and those of the space outside the SEZ (heterogeneous space) on the macroenvironment. On the other hand, the "OLS (Robust)" method is used to measure the effects of production variables over the period 2014-2022 by focusing on static impacts.

The second approach is an exploratory descriptive analysis using principal component analysis (PCA) to study the correlations between the different variables and to visually examine the behavior of the observations in each of the two spaces. These methods applied to the Gabonese context aim to understand the effects of the Nkok SEZ, to highlight the regional disparities between the SEZ and its external environment, as well as to explain the mechanisms of endogenous growth in the country's forestry sector.

### Introducing the SEMD Model

#### Definition and originality of the SEMMD model

The SEMMD (Segmentation, Evaluation and Management of Multi-level Disparities) model is an analytical and operational framework designed to identify, measure and correct spatial and socio-economic inequalities generated by asymmetric territorial dynamics, particularly around Special Economic Zones (SEZs) and industrial hubs.

This model is based on three main pillars:

- A **fine and multi-level spatial segmentation**, which distinguishes six types of economic and geographical spaces (SEZs, agglomerated secondary industries, logistics corridors, local markets, rural peripheral areas and secondary/informal circuits) to capture the real complexity of centre-periphery interactions and the functional diversity of territories.
- A **quantitative and qualitative assessment** integrating both classic indicators (productivity, FDI, transformation rate) and hybrid measures (technological absorption capacity, financial inclusion), allowing us to simultaneously understand the economic performance and the social and institutional dimensions of development.
- **management of disparities**, combining vertical channels of diffusion (income transfers, local subcontracting, technology transfers) and horizontal equalization channels (investments in infrastructure, adapted training, regional sovereign wealth funds), as well as real-time management through geospatial dashboards and artificial intelligence tools.

#### Differences and originality compared to other models

Unlike traditional approaches to assessing regional or sectoral disparities, which are often centered on aggregate and static indicators (such as regional GDP gaps or human development indices), the SEMMD offers a **multi-level and multi-scale reading**, finely distinguishing the roles and functions of central and peripheral spaces, while taking into account the informal economy and secondary circuits often ignored by classical models.

Compared to **growth pole models (Perroux, 1955)** or **spatial equilibrium** frameworks (Krugman, 1991), which primarily describe the logics of concentration and polarization, the SEMMD stands out by integrating institutional and financial levers explicitly designed to **institutionalize the**

**redistribution and diffusion** of growth effects to the peripheries. Inspired by Hirschman (multiplier effects) and Myrdal (cumulative causality), it goes beyond simple diagnosis to construct a **framework for territorial rebalancing**.

Finally, its originality also lies in the combined use of **advanced analytical tools** (DEA, spatial models, input-output analyses), geospatial data, and real-time adaptive control. This approach makes it particularly relevant for supporting contemporary strategies for inclusive and sustainable industrialization in developing countries, reconciling economic performance and territorial cohesion.

In summary, the SEMMD is an integrative and operational model, distinguished by its ability to **describe, measure and act** on territorial inequalities, taking into account the real complexity of economic and social systems, while proposing concrete corrective mechanisms and dynamic management adapted to changing contexts.

## II.2. Data sources

The software used to carry out the estimations and descriptive statistics is stata 18, R and XLSTAT. To carry out this study, five (5) macroeconomic variables, outside and in the Nkok SEZ, were selected (Table 2).

The data series used for the homogeneous space ( In the Nkok SEZ) were obtained from secondary documentary sources from the Ministry of the Economy of Gabon (Dashboard of the economy of Gabon from 2014 to 2022). The dashboards contain annual statistics on the economic performance of the timber sector in general and the Special Economic Zone of Nkok (In the Nkok SEZ) in particular. The data series used for the “macroenvironment” space were obtained from the FAOSTAT database which contains aggregated macroeconomic variables of the forestry sectors of countries around the world. The variables are described as follows:

**Table 2.** Description of variables.

Variable	Stand point	Unit	Source
EXP_T <sub>USD</sub> (Export Income).	Dependent Variable	Million dollars (USD)	<ul style="list-style-type: none"> <li><b>Source 1:</b> FAOSTAT (Link: <a href="https://www.fao.org/faostat/en/#data/FO">https://www.fao.org/faostat/en/#data/FO</a> ).</li> <li><b>Source 2:</b> Dashboard of the Gabonese economy (Link: <a href="http://www.dgepf.ga/23-publications/25-table-de-bord-de-l-economie/169-table-de-bord-de-l-economie/">http://www.dgepf.ga/23-publications/25-table-de-bord-de-l-economie/169-table-de-bord-de-l-economie/</a> ).</li> <li><b>Source 3:</b> EY and Mays Mouissi Consulting (2023) ( Link: <a href="https://www.mays-mouissi.com/?utm">https://www.mays-mouissi.com/?utm</a> ).</li> </ul>
EXP_T <sub>m3</sub> (Forestry Exports).	Independent variable	Cubic meter (m <sup>3</sup> )	
Ind_P_T <sub>m3</sub> (Industrial Forestry Production).	Independent variable	Cubic meter (m <sup>3</sup> )	
Ind_P_Ven <sub>m3</sub> ( Veneer wood) industrial production).	Independent variable	Cubic meter (m <sup>3</sup> )	
Ind_P_SAWN <sub>m3</sub> (Sawn timber industrial production).	Independent variable	Cubic meter (m <sup>3</sup> )	

## II.3. Modeling

### II.3.1. General Panel Model

Equation (1) with is the general model with k predictors allowing estimates to be made in panel data econometrics. This equation requires transformations for practical applications leading us to equations (2, 3, 4 and 5).

$$y_{it} = \sum_{j=1}^p \binom{p}{j} \beta_{ji} X_{jit} + \omega_{it} \quad (1)$$

### II.3.2. Estimation by method “ Fixed Effect-Bias-Corrected Estimation (Robust)”

The study proposes four bias-corrected estimation models for linear dynamic panel data, applied to three types of geographical spaces (In the Nkok SEZ, outside the Nkok SEZ and the

macroenvironment). These models make it possible to carry out four regressions on unbalanced panels, with N=2 and T=9 (for the spaces “In the Nkok SEZ” and “Outside the Nkok SEZ”) and T=53 (for the macroenvironment). The results obtained make it possible to analyze the distribution of points in the cloud and to explain the imbalances between the spaces “ In the Nkok SEZ”, “Outside the Nkok SEZ” and the macroenvironment.

The general form of the “Bias-Corrected Estimation of linear dynamic panel data models” model is as follows:

$$y_{it} = \sum_{j=1}^p \binom{p}{j} \lambda_j y_{i,t-j} + X_{it}\beta + \alpha_i + u_{it}, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T \quad (2)$$

$$\omega_{it} = \alpha_i + u_{it} \quad (3)$$

The basic model assumptions are as follows:

- The minimum individual and temporal dimensions are N=2 and T=2, they can extend to infinity (Breitung, Kripfganz, and Hayakawa, 2021) [43].

$$i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T$$

- The autoregressive (higher order) model with P lags of the dependent variable and only minimal regularity conditions on the initial observations;
- The strictly exogenous regressors  $x_{it}$  with respect to the idiosyncratic error term are:

$$E[x_{it}u_{is}] = 0 \text{ for all } t \text{ and } s; \quad (4)$$

- For Fixed Effects specific and random to unobserved groups,

$$E[x_{it}\alpha_i] \neq 0, \text{ or “random effects” } E[x_{it}\alpha_i] = 0. \quad (5)$$

- Serially Uncorrelated Idiosyncratic Errors are as follows:

$$E[u_{it}u_{is}] = 0 \text{ for all } t \text{ and } s \text{ and } E[u_{it}^2] = \sigma_i^2. \quad (6)$$

For simplicity, let  $p = 1$  and define  $\theta = (\lambda_1, \beta')'$ . The Fixed Effect Bias Corrected (FE-BC) estimator that has just been identified solves:

$$\hat{\theta} = \arg \min (\sum_{i=1}^N m_i(\theta))' (\sum_{i=1}^N m_i(\theta)) \quad (7)$$

With the moment of the function which is calculated as follows:

$$m_i(\theta) = \frac{1}{T} \sum_{t=1}^T \left[ \begin{pmatrix} y_{i,t-1} - \bar{y}_{i,t-1} \\ x_{i,t} - \bar{x}_i \end{pmatrix} \begin{pmatrix} \frac{T}{T-1} b(\lambda_1) (e_{it} - \bar{e}_i) \\ 0 \end{pmatrix} \right] e_{it} \quad (8)$$

$$\bar{x}_i = \frac{1}{T} \sum_{t=1}^T x_{it} \text{ and } b(\lambda_1) = \frac{1}{T^2} \sum_{t=0}^{T-2} x_{it} \sum_{s=0}^t x_{it} \lambda_1^s \quad (9)$$

$$\text{With, } E[m_i(\theta)] = 0 \quad (10)$$

(Breitung, Kripfganz, and Hayakawa, 2021) [43].

Equations 11, 12, 13 and 14 illustrate the “Fixed Effect-Bias-Corrected Estimation (Robust)” method. And equations 15, 16, 17 and 18 illustrate the “OLS (Robust)” method.

$$Y_{1(it)} = \beta_0 + \lambda_1 Y_{1,t-1(it)} + \beta_1 * X_{1(it)} + \omega_{1(it)} \quad (11)$$

$$Y_{2(it)} = \beta'_0 + \lambda_2 Y_{2,t-1(it)} + \beta_2 * X_{2(it)} + \omega_{2(it)} \quad (12)$$

$$Y_{3(it)} = \beta''_0 + \lambda_3 Y_{3,t-1(it)} + \beta_3 * X_{3(it)} + \omega_{3(it)} \quad (13)$$

$$Y_{4(it)} = \beta'''_0 + \lambda_4 Y_{4,t-1(it)} + \beta_4 * X_{4(it)} + \omega_{4(it)} \quad (14)$$

- $Y$  = Export revenues from Gabon’s woody forest products. (Exp\_TUSD) .
- $Y_{i,t-j(it)}$  = The lagged dependent variable.
- $\lambda_j$  = Regression coefficient of the autoregressive variable.
- $X_1$  = Volume of exports of wood forest products from Gabon (Exp\_Tm3).
- $X_2$  = Total industrial production of wood forest products in volume (m<sup>3</sup>) in Gabon (Ind\_P\_Tm3).
- $X_3$  = Industrial production of sawn wood in volume (m<sup>3</sup>) in Gabon (Ind\_P\_Venm3).
- $X_4$  = Industrial production of veneer wood in volume (m<sup>3</sup>) in Gabon (Ind\_P\_SAWNm3).
- $\beta_j$  = Regression coefficients of independent variables.

### III.3.3. Estimation by “OLS (Robust)” method

OLS models make it possible to model imbalances within (internal disparities) of homogeneous and heterogeneous spaces (equations 15, 16, 17 and 18) during the process of polarization of the forestry sector in Gabon over the period 2014-2022, using a non-parametric estimation method ("OLS (Robust)") with  $T=9$ .

$$Y_1(t) = \beta_0 + \beta_1 * X_{1(t)} + \omega_{1(t)} \quad (15)$$

$$Y_2(t) = \beta'_0 + \beta_2 * X_{2(t)} + \omega_{2(t)} \quad (16)$$

$$Y_3(t) = \beta''_0 + \beta_3 * X_{3(t)} + \omega_{3(t)} \quad (17)$$

$$Y_4(t) = \beta'''_0 + \beta_4 * X_{4(t)} + \omega_{4(t)} \quad (18)$$

### III.3.4. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was carried out to determine the correlations between the different variables of interest in the forestry sector selected for this study in order to explain the mechanisms around the dynamics of unbalanced growth of spaces.

The PCA allowed the graphical representation of all individuals (temporal data) according to all the measured parameters which describe them (the quantitative variables studied). In this study, the graph of individuals will not be used because the individuals correspond to the time series. The graphical analysis of temporal data is not relevant for this PCA. The five (5) variables studied in PCA represent vectors in a space with 5 artificial dimensions and each dimension is denoted  $F$  ( $F_1$  for the first and,  $F_2 \dots F_5$  for the others). The information is projected on all dimensions. Only the information carried by the two dimensions which maximizes the information is observed on a correlation circle ( $F_1, F_2$ ). We therefore obtain a synthetic and trendy vision of the situation, which brings together all of the variables studied (5 quantitative variables). All the variables studied in this PCA are active (Husson, 2018) [44].

- **Correlation matrix**

The correlation matrix makes it possible to precisely highlight the intensities of correlations between variables using correlation coefficients. Significance tests of the correlations were carried out using the Bartlett test of sphericity at the 95% confidence threshold. The associated critical probabilities are at the threshold of  $\alpha = 0.05$ . To identify significant correlations, the correlation coefficients were bolded in the correlation matrix. (Husson, 2018) [44].

- **Correlation circle**

The correlation circle (or variable plot) shows the correlations between the components and the initial variables (Figure 1). Additional variables can also be displayed as vectors.

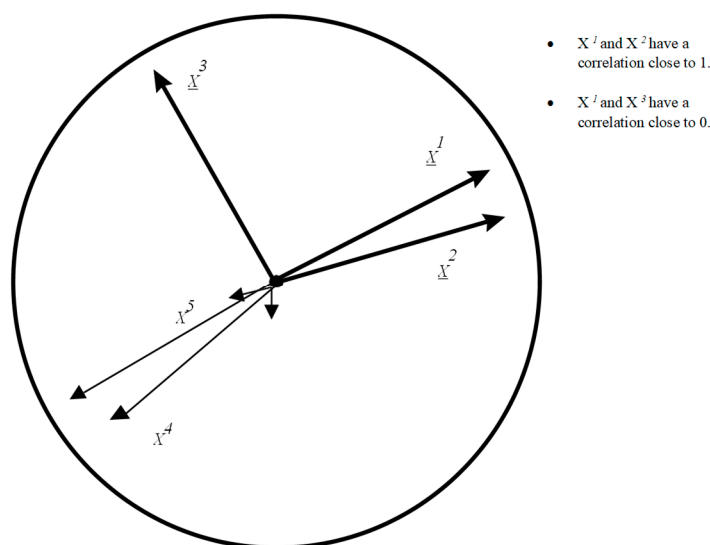


Figure 1. Illustration of the Correlation Circle ( Husson, 2018) [44].

- **Correlation coefficient**

The data  $\underline{X}^i$  And  $\underline{X}^j$  represents the components or correlated variables.

$$\text{Cos}(X^i, X^j) = \frac{[\underline{X}^i, \underline{X}^j]}{\|\underline{X}^i\| \|\underline{X}^j\|} = \frac{\text{cov}(\underline{X}^i, \underline{X}^j)}{s_i s_j} = R(\underline{X}^i, \underline{X}^j) \quad (6)$$

$$R(\underline{X}^i, \underline{X}^j) \quad (7)$$

The value  $R$  represents the correlation coefficient which determines the relationship between the noted variables:  $\underline{X}^i$  And  $\underline{X}^j$ .

$$\text{Cos}(X^i, X^j) \quad (8)$$

Equation (8) is the cosine which allows us to determine the angles formed by the axes or variables

The cosine of the angle formed by the variables  $X^i$  and  $X^j$  is the linear correlation coefficient of these two variables.

Settings  $s_i$  And  $s_j$  are the Standard deviation of  $\underline{X}^i$  And  $\underline{X}^j$ . (Husson, 2018) [44]

### III. Results

#### III.1. Statistical description

The table (Table 3) presents the descriptive statistics on the microenvironmental variables of interest used for the study.

Table 3. Statistical description.

Variables	Obs	Mean	STD. Dev.	Min	Max
Exp_T USD	71	327.0783	262,216	4	1036.298
Exp_T m <sup>3</sup>	71	2362457	1219393	5807.998	4570000
Ind_P_T m <sup>3</sup>	71	1840331	837329.9	6798.346	3,500,000
Ind_P_SAWN m <sup>3</sup>	71	297814.2	307272	2993.489	1297580
Ind_P_Ven m <sup>3</sup>	71	142864.4	119461	2000	589181

Table 4. Exports in volume depending on space.

Total exports in volume (m <sup>3</sup> )			
Years	In Nkok SEZ	Out Nkok SEZ	Macro-Environment
2014	5807.998163	3264192.002	3270000
2015	23489.48057	3046510.519	3070000
2016	63220.06	3006779.94	3070000
2017	171354.2	3198645.8	3370000
2018	219696	2884304	3104000
2019	371668	2837332	3209000
2020	417297	3571288	3988585
2021	540788	3447797	3988585
2022	549043	3258890.597	3807933.597

Source: Gabon Economy Dashboard and the FAOSTAT database.

Table 5. Export revenues depending on space.

Exports (Millions USD)			
Years	In Nkok SEZ	Out Nkok SEZ	Macro-Environment
2014	4	459,491	463,491
2015	16.17733	490.5607	506.738
2016	43.54	431.119	474.659

2017	73.028	486,347	559.375
2018	81	452	533
2019	137	459	596
2020	165	517	682
2021	380	439	819
2022	511	506	1017

**Source:** *Gabon Economy Dashboard and the FAOSTAT database.*

In the homogeneous space, all the variables have higher growth dynamics than those of the heterogeneous space which also represents the periphery.

The figures below (Figures 4–7) present industrial and commercial relations in the three types of economic and geographical spaces studied. Figure 4 allows us to analyze the effects of export revenues in the homogeneous space ( In Nkok SEZ ) and Figure 5 allows the analysis of the effects of export revenues in the heterogeneous space (Out Nkok SEZ ). While Figures 6 and 7 allow us to analyze the influences of the variables of homogeneous and heterogeneous spaces on the variables of the macroenvironment.

#### III.4. Effects of export revenues in homogeneous space

From the observations of the scatter plots in Figure 4 (and Appendix A ) and the estimates of the effects of export revenues in the homogeneous space, we can conclude that during the period 2014 to 2015 export revenues had strong effects on the growth of exports and industrial production of woody forest products in the homogeneous space. In fact, we record regression coefficients ranging from 84 to 97%. Therefore, an increase in corporate export revenues of 100% of the homogeneous space leads to increases of 94% for exports and increases in industrial production ranging from 84 to 97% over the period 2014 to 2022. The fact that the homogeneous space strongly specializes in industrial transformation with strategic competitive advantages compared to heterogeneous space illustrates the effects of “Big Push” theorized by Rosenstein-Rodan (1943) [45] associated with the center-periphery effects of Friedman (1966) [14].

But still, according to Krugman, P. (1991) [15], economies of scale (increasing profits due to production in large quantities) encourage companies to group together in certain regions (notably Special Economic Zones) to minimize costs. production costs and benefits from proximity to markets. This phenomenon is fueled by the agglomeration effects initially theorized by Perroux (1955) [1] and Hirschman (1958) [11] (notably the agglomeration of companies, talents, capital, product innovation and industrial processes) generating a virtuous circle of development. However, Krugman, P. (1991) [15], clearly indicates that the phenomenon reinforces disparities between regions, since developed areas (notably homogeneous space) continue to grow while others (such as heterogeneous space) stagnate.

#### III.5. Effects of export revenues in heterogeneous space

In the heterogeneous space (Figure 5 and Appendix A), we note that export revenues do not provide sufficiently significant effects on the growth of exports of goods and industrial production over the period 2014 to 2022. These observations find their explanations in unbalanced regional growth theories. Indeed Myrdal (1957) [7] states that unbalanced regional growth is capable of generating downward trends of negative reactions in peripheral regions, and this can cause and widen regional disparities. According to him, these disparities are created due to market mechanisms, generating “backwash” effects that are much more significant than these “spread” effects, and the interactions between these two effects will lead to the worsening of regional disparities. But again, the “ center-periphery” theories of Friedman (1966) [14] and the work of Perroux (1955) [1] on the transformation of industrial relations between the center and the periphery are also illustrated. Agglomeration economies and infrastructures in the homogeneous space force many firms to locate in the peripheral regions of the heterogeneous space, in order to extract woody forest resources and supply them in the homogeneous spaces. This reorganization of the Gabonese

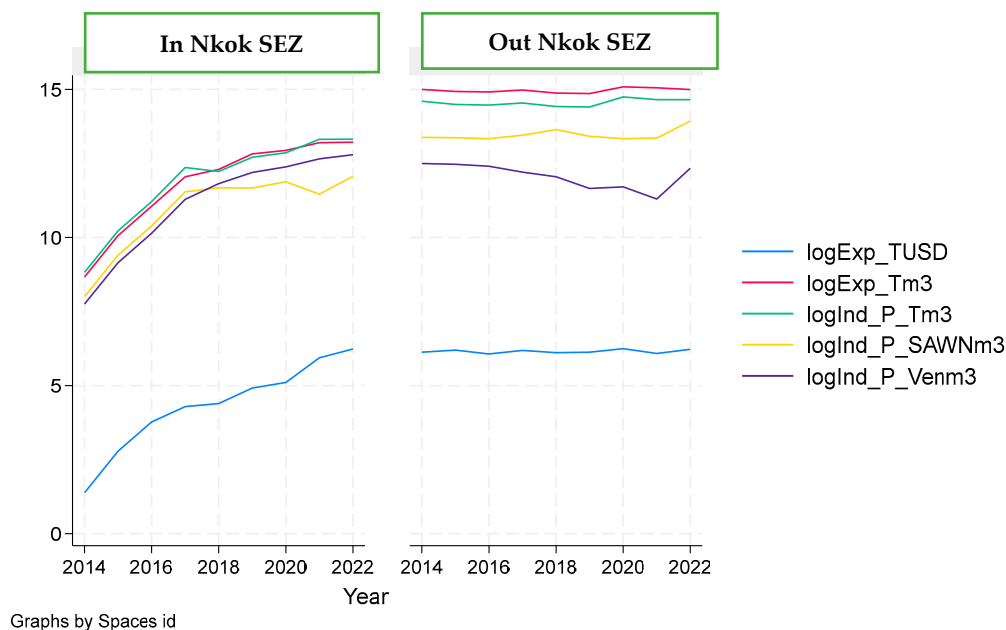
forest industrial matrix is demonstrated by the relationships observed from estimates in homogeneous and heterogeneous spaces, showing an accelerated polarization process.

### III.6. Effects of export revenues from homogeneous space on the macroenvironment

In terms of influences, when we study the effects of export revenues from the homogeneous space on the macroenvironment variables (Figure 6 and Appendix B) observed in isolation, we see that the effects are stronger than those of the heterogeneous space concerning the autoregressive effects of export income. Indeed, the dynamic parts of the models indicate that the lagged autoregressive dependent variables vary from 77% to 94% in homogeneous space. Thus, over the period 2014-2022, an increase in export revenues of 100% for a given year (n) leads to increases in export revenues ranging from 77% to 94% the following year (n+1) in homogeneous space. While for the effects on industrial production variables, the Nkok Special Economic Zone (homogeneous space) generates effects ranging from 6 to 25% on macroenvironment variables when export revenues from the homogeneous space increase by 100%.

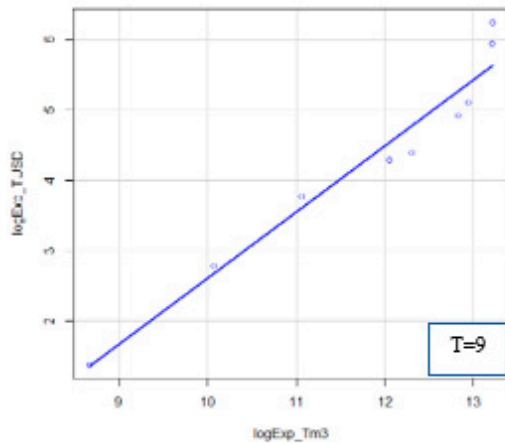
### III.7. Effects of export revenues from heterogeneous space on the macroenvironment

In the same time interval, the effects of export income from the heterogeneous space on the macroenvironment variables (Figure 7 and Appendix B) observed in isolation, are less strong than those from the homogeneous space concerning the autoregressive effects of income of exports. Indeed, the dynamic parts of the models indicate that the lagged autoregressive dependent variables vary from 69% to 88% in the heterogeneous space. So, over the period 2014-2022, an increase in export revenues of 100% for a given year (n) leads to increases in export revenues ranging from 69% to 88% the following year (n+1) in heterogeneous space. While for the industrial production variables of the heterogeneous space, they have effects ranging from 8 to 59% on the macroenvironment variables when the export revenues of the heterogeneous space increase by 100%. Which shows that there is still a predominance of the effects of heterogeneous space compared to homogeneous space concerning industrial production in volume in the macroenvironment. However, the growth dynamics of the variables as well as the effects of export revenues are much stronger within the homogeneous space.



**Figure 3.** Growth dynamics of variables in homogeneous and heterogeneous spaces.

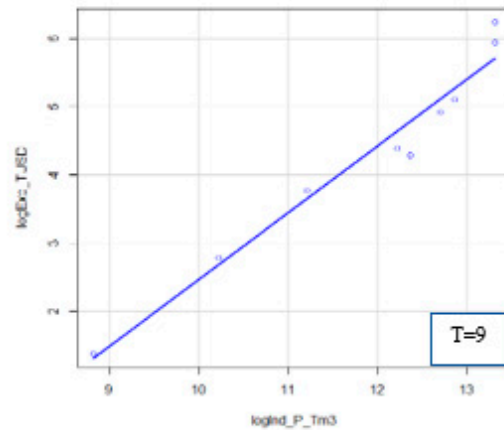
Illustration of the effect of export revenues in the homogeneous space ( In Nkok SEZ )



$$Y_1(t) = -6.77 + 0.929 * X_1(t) + \omega_1(t)$$

**R<sup>2</sup>=0.939      p. value=0.000**

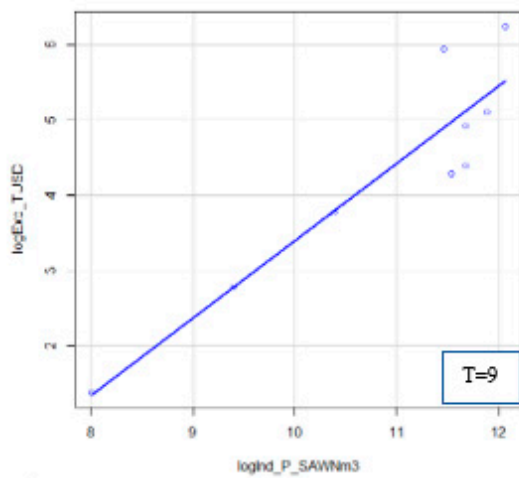
*Fig.4a. Effects of export revenues on exports of wood products in the Nkok SEZ.*



$$Y_2(t) = -7.31 + 0.968 * X_2(t) + \omega_2(t)$$

**R<sup>2</sup>=0.952      p. value=0.000**

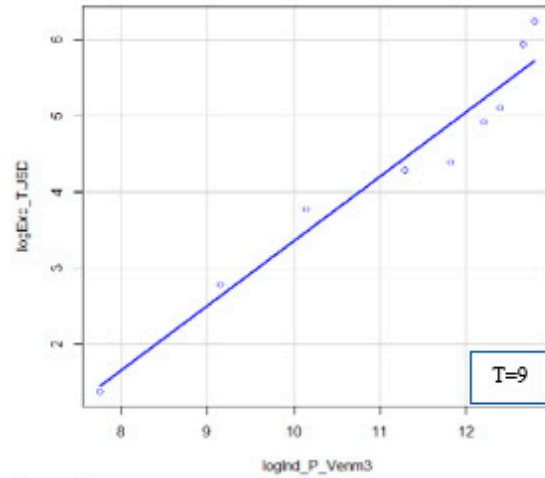
*Fig.4b. Effects of export revenues on total industrial wood production in the Nkok SEZ.*



$$Y_3(t) = 2.30 + 0.956 * X_3(t) + \omega_3(t)$$

**R<sup>2</sup>=0.996      p. value=0.000**

*Fig.4c. Effects of export revenues on sawn wood production in the Nkok SEZ.*



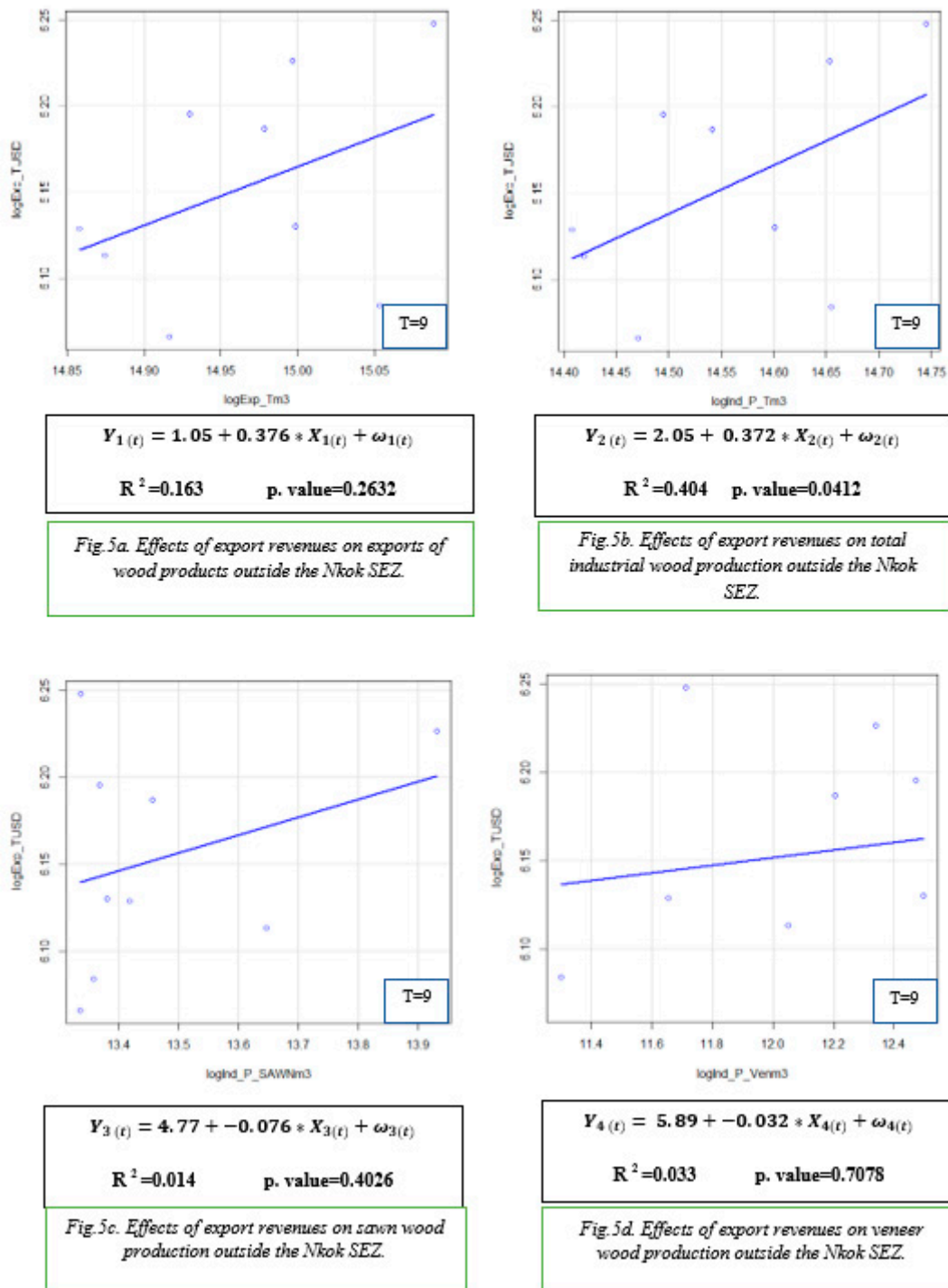
$$Y_4(t) = -5.1 + 0.841 * X_4(t) + \omega_4(t)$$

**R<sup>2</sup>=0.927      p. value=0.000**

*Fig.4d. Effects of export revenues on veneer wood production in the Nkok SEZ.*

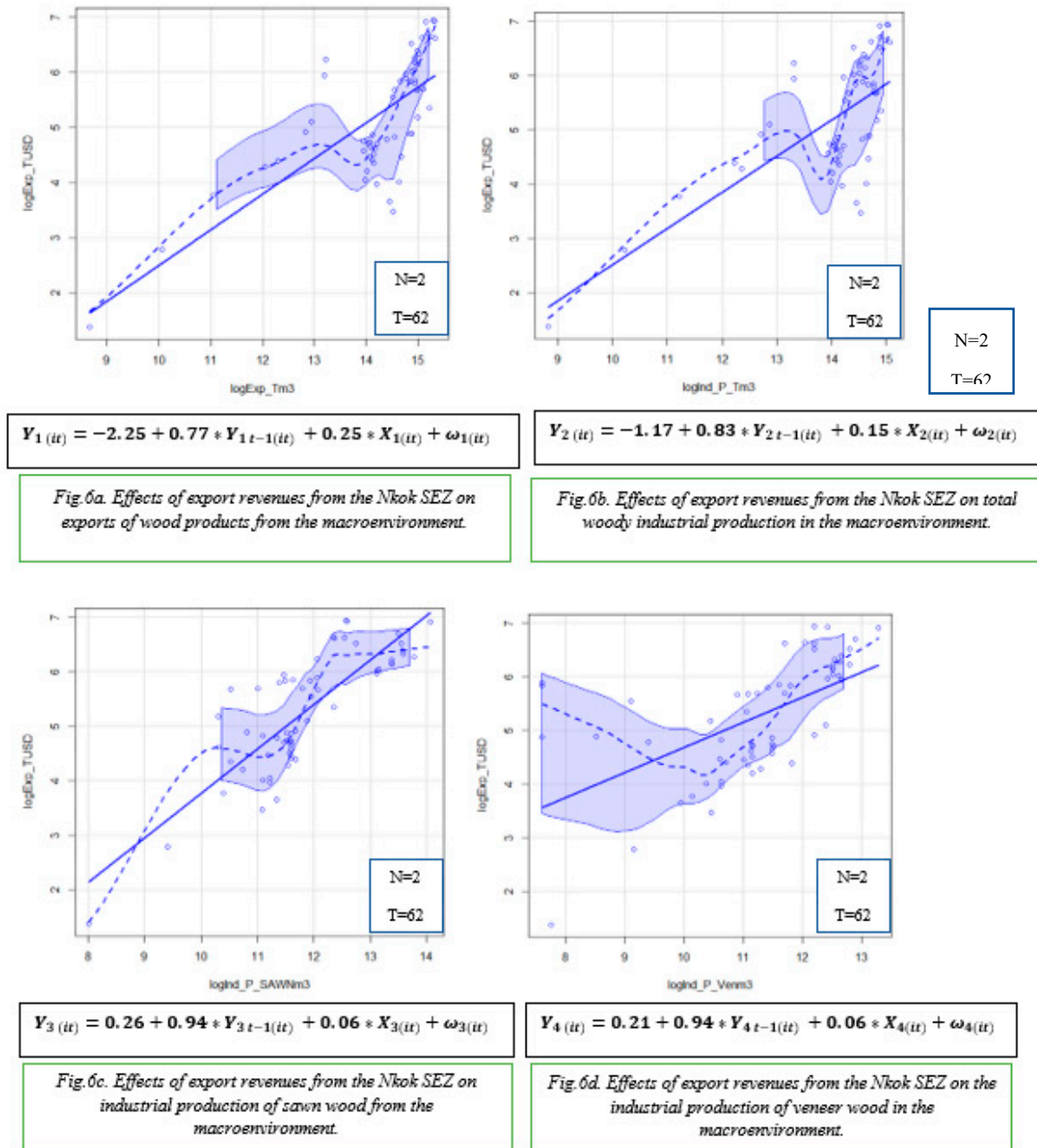
**Figure 4.** Scatterplot illustrating the effects of export revenues from woody forest products within the homogeneous space ( In Nkok SEZ ).

*Illustration of the effect of export revenues in the heterogeneous space (Out Nkok SEZ)*



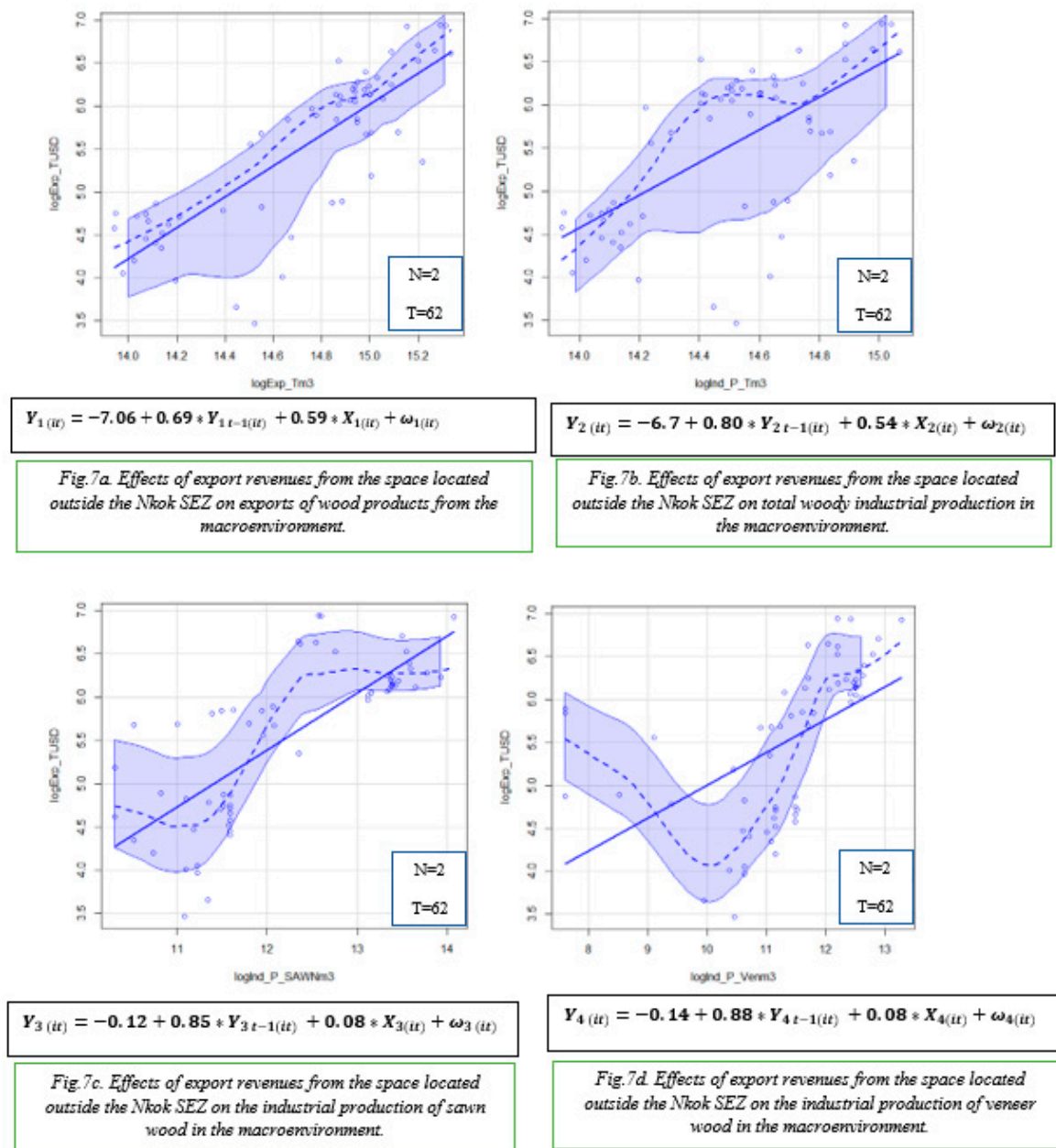
**Figure 5.** Scatterplot illustrating the effects of export revenues from woody forest products within the heterogeneous space ( Out Nkok SEZ ).

*Illustration of the effect of export revenues from homogeneous space on the macroenvironment*



**Figure 6.** Scatter plot illustrating the effects of export revenues from woody forest products from homogeneous space on macroenvironment variables.

*Illustration of the effect of export revenues from heterogeneous space on the macroenvironment*



**Figure 7.** Scatter plot illustrating the effects of export revenues from woody forest products from heterogeneous space on macroenvironment variables.

**III.8. Principal component analysis (PCA)**

**III.8.1. Bartlett's test of sphericity**

Bartlett's test of sphericity (Table 6) indicates that there are at least two significantly correlated variables (p-value (two-sided) <0.0001).

**Table 6.** Bartlett's test of sphericity.

Statistics	Values
Chi <sup>2</sup> (Observed value)	480.185
Chi <sup>2</sup> (Critical value)	18.307
DDL	10

p.value (two-sided)	<0.0001
Alpha	0.05

$H_0$ : There is no correlation significantly different from 0 between the variables.  $H_1$ : At least one of the correlations between the variables is significantly different from 0. Given that the calculated p-value is lower than the significance level  $\alpha=0.05$ , we must reject the null hypothesis  $H_0$ , and retain the alternative hypothesis  $H_1$ .

### III.8.2. Biplot and correlation matrix

The Biplot (Figure 8 and Appendix C) shows that the first component ( $F_1$ ) represents 71.64% of the inertia and the second component ( $F_2$ ) 18.76%, these first two main components therefore explain 90.40% of the total inertia (Figure 8 and Appendix C). All variables, that is to say, export revenues from woody forest products ( $Exp\_T_{USD}$ ), the total volume of exports from woody forest products ( $Exp\_T_{m3}$ ), the total sum of production (processed and unprocessed) industrial sawn wood production of companies in the woody forestry sector ( $Ind\_P\_T_{m3}$ ), the total sum of industrial sawn wood production of companies in the sector woody forestry sector ( $Ind\_P\_Ven_{m3}$ ), the total sum of industrial veneer wood production of companies in the woody forestry sector ( $Ind\_P\_SAWN_{m3}$ ) form angles less than 90 degrees. This means that all these variables are positively correlated with each other.

Concerning the correlation matrix (Table 7), the national volume of exports of woody forest products ( $Exp\_T_{m3}$ ) and the total sum of industrial production (processed and unprocessed) of companies in the woody forestry sector ( $Ind\_P\_T_{m3}$ ) are strongly correlated ( $R=0.990$ ). When we look at the correlations between export revenues and production variables, we see that they are strongly and respectively correlated with the total sum of industrial sawn wood production of companies in the woody forestry sector ( $R=0.823$ ), to the total sum of industrial production (processed and untransformed) of companies in the woody forestry sector ( $R=0.678$ ) and finally to the total sum of industrial sawn wood production of companies of the woody forestry sector ( $R=0.605$ ).

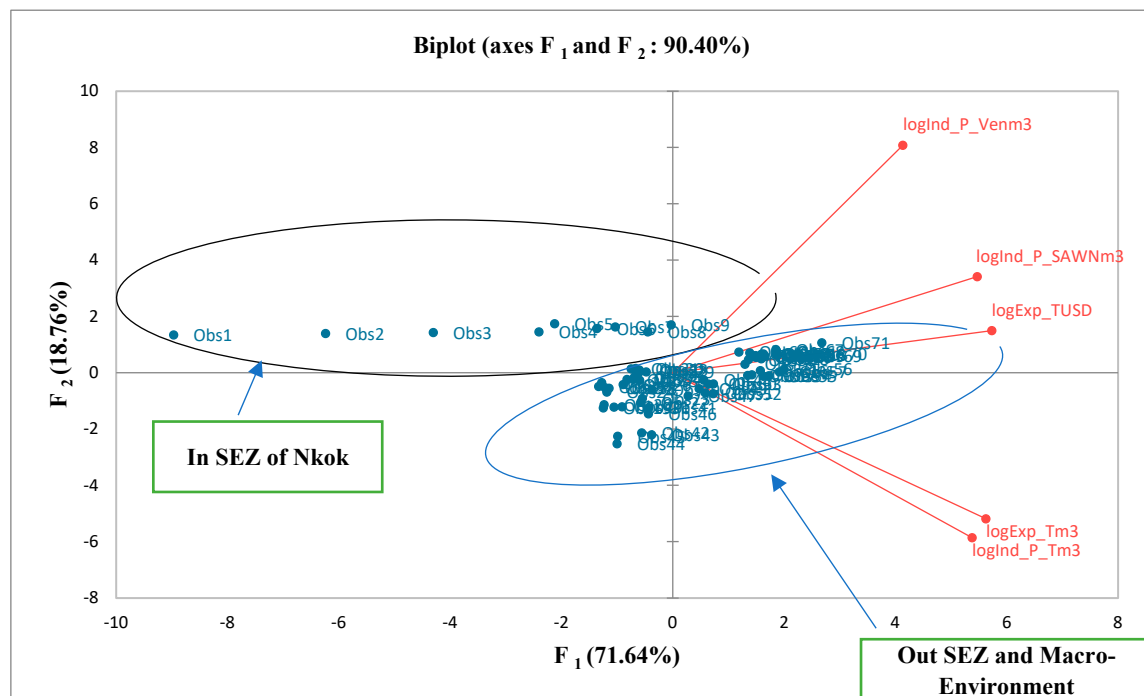


Figure 8. Biplot (combination of the correlation circle with the observation graph).

Table 7. Correlation Matrix.

Variables	LogInd_P_T <sub>m3</sub>	LogInd_P_SAWN <sub>m3</sub>	LogInd_P_Ven <sub>m3</sub>	LogExp_T <sub>USD</sub>	LogExp_T <sub>m3</sub>
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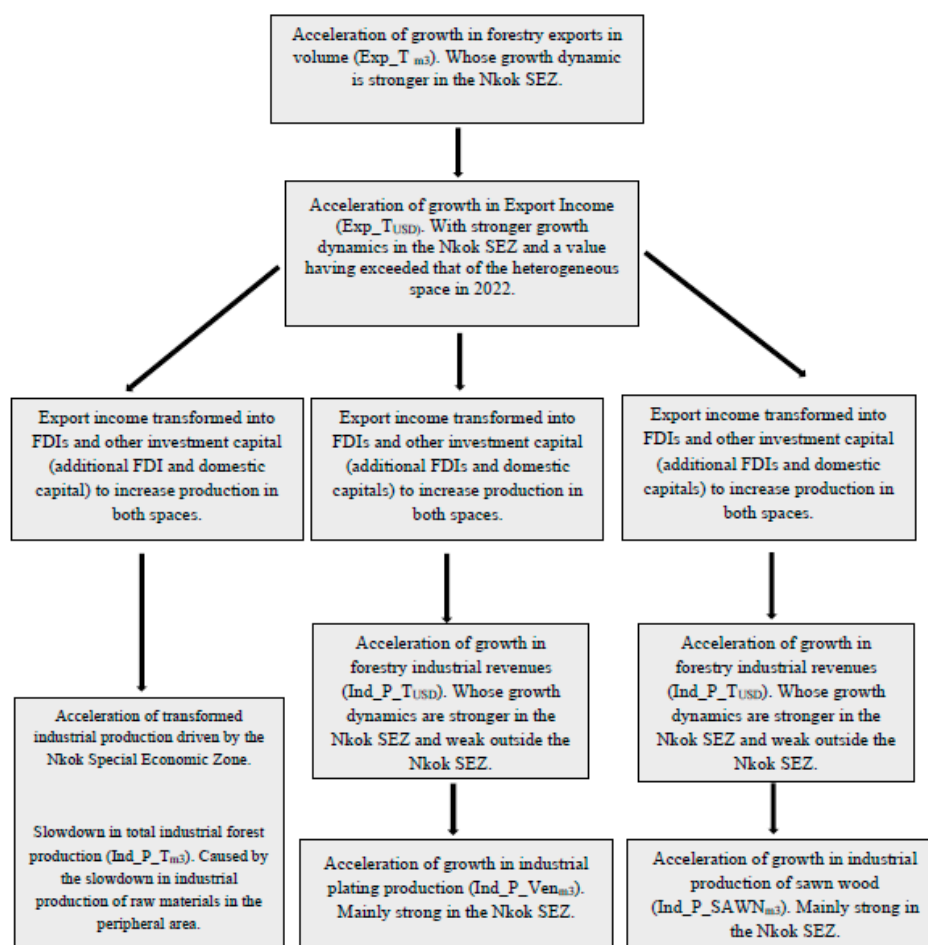
LogInd_P_T <sub>m3</sub>	<b>1</b>				
LogInd_P_SAWN <sub>m3</sub>	<b>0.573</b>	<b>1</b>			
LogInd_P_Ven <sub>m3</sub>	<b>0.312</b>	<b>0.651</b>	<b>1</b>		
LogExp_T <sub>USD</sub>	<b>0.678</b>	<b>0.823</b>	<b>0.605</b>	<b>1</b>	
LogExp_T <sub>m3</sub>	<b>0.990</b>	<b>0.646</b>	<b>0.348</b>	<b>0.737</b>	<b>1</b>

Values in bold are different from 0 at a significance level  $\alpha=0.05$ .

### III.9. Mechanisms of imbalance in economic and geographical spaces of the woody forest sector in Gabon

The conditions met generate a process of transformation of the industrial matrix (Figure 9) by differentiating and specializing activities according to the space considered. The homogeneous region, more oriented towards exports, represents a real strong driving industry for downstream and upstream activities. While the heterogeneous region brings together secondary and primary driving activities (less stronger than those of the homogeneous region), providing raw materials to the homogeneous space which has more of an industrialization and export function. The acceleration of forest exports in volume (Exp\_T<sub>m3</sub>) whose growth dynamic is stronger in the Nkok SEZ generates an acceleration in export revenues (Exp\_T<sub>USD</sub>).

*Illustration of the mechanisms of imbalance in economic and geographical spaces of the woody forestry sector in Gabon*



**Figure 9.** Causality diagram which illustrates industrial and commercial relations in the polarized economic and geographical spaces of Gabon's forestry sector.

With a stronger growth dynamic in the Nkok SEZ and a value having exceeded that of the heterogeneous space in 2022. Then export revenues will be gradually transformed into FDIs and other investment capital (additional FDIs and domestic capitals) to increase production in both spaces (homogeneous and heterogeneous) while strongly accelerating those in the homogeneous space to the detriment of those in the heterogeneous space from year to year. Finally, two simultaneous effects are observed in both spaces, illustrating Friedman's "center-periphery" theory (1966) [14]. This is the acceleration of industrial production transformed and carried by the Special Economic Zone of Nkok (homogeneous space) accompanied by a slowdown in total forestry industrial production (Ind\_P\_T<sub>m3</sub>) caused by declines in industrial production of raw materials from the peripheral area.

### Conceptual framework of the SEMMD model

The SEMMD model (Segmentation, Evaluation, and Management of Multi-Level Disparities) offers an innovative and systemic approach to analyzing, measuring, and correcting territorial inequalities exacerbated by the establishment of Special Economic Zones (SEZs) and industrial hubs, particularly in underdeveloped regions of the Global South. Built around three pillars—spatial segmentation, multi-level evaluation, and disparity management—SEMMD aims to go beyond simply identifying gaps to build an operational and evolving framework for rebalancing.

#### 1. Segmentation

The first step relies on a detailed spatial segmentation, distinguishing six types of economic and geographical spaces with complementary functions: Special Economic Zones (SEZs), planned hubs concentrating foreign direct investment and advanced industrial processing; agglomerated secondary industries, spontaneous hubs oriented towards local markets; logistics corridors ensuring the circulation of raw materials and processed products; local markets, large and small, absorbing production; peripheral rural areas, the main providers of natural and agricultural resources; and finally, secondary and informal circuits, often fragile but essential for employment and territorial resilience. This typology sheds light on center-periphery interactions and the unequal dynamics of concentration and diffusion within value chains.

Figure 3 illustrates six (6) types of economic and geographic spaces, including the SEZ, which exerts the main forces of imbalance on the other five (5) types of spaces, in the case of value chains based on natural resources that can be exploited by farming communities. These include forestry, fisheries and certain mining resources. The unbalanced growth model based on SEZs specializing in the processing of living natural resources in underdeveloped regions of the South that we propose is made up of six (6) types of economic and geographic spaces (Figure 3). The economic and geographic spaces polarized from SEZs have diverse characteristics and play roles that are both distinct and complementary. They are as follows:

**1. SEZs:** *Their mission is to carry out advanced transformations and stimulate the industrialization of sectors*

Consisting of motor and propelled industries (Figure 3), SEZs are geographically localized and constitute the bulk of the industrial matrix of the sector in underdeveloped regions of developing countries using SEZs as industrialization instruments and strategies. They are mainly export-oriented and generate the cumulative circular causation effects theorized by Myrdal (1957) [2], the polarization effects theorized by Perroux (1955) [1] and Hirschman (1958) [3] and play the role of center presented and theorized by Friedman (1966) [5], also known as "center-periphery" (Friedman, 1966) [5]. In SEZs, raw material processing in underdeveloped regions generally involves the first transformation, and the second is also important. Third transformation is absent or weak in the vast majority of cases, due to the integration and structuring of global value chains in their current state, which end in industrialized countries.

**2. Agglomerated secondary motor industries:** *Less advanced transformation*

Agglomerated secondary power industries are power units located outside the homogeneous area (ie, outside Special Economic Zones). They exert polarization effects (diffusion, links and agglomeration), cumulative circular causation effects at lower intensities than those of the main poles, and play the role of secondary centers (Figure 3). They are made up of secondary motivated units

and secondary propelled motivated units. They are supplied with resources from peripheral areas and generally carry out primary processing activities. Products from agglomerated secondary power plants are mainly sold in large local markets. One of the main differences between agglomerated secondary industries and main clusters (SEZs) is that secondary clusters or agglomerated secondary industries are formed spontaneously, whereas SEZs are economic and geographic spaces planned by governments and private firms. Central governments in the case of developing countries.

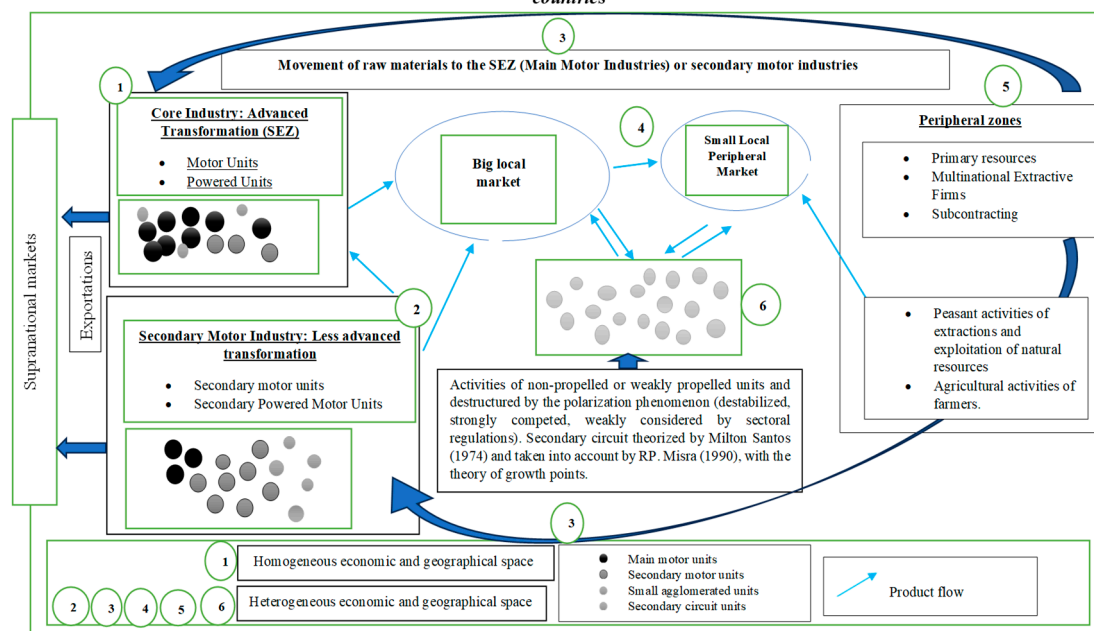
2. **Moving raw materials:** Allows the flow of raw materials and serves as a corridor for production units

The movement of raw materials to SEZs (primary drive industries) or secondary drive industries agglomerated in the underdeveloped territories and regions of developing countries is relatively low for sub-Saharan African countries compared to those in Asia or Latin America. In fact, major road, rail, port and airport infrastructure requirements are proving to be major challenges for large-scale flows of raw materials between different economic and geographical areas (Figure 3).

3. **Local markets:** Large local markets and Small local markets

In sub-Saharan Africa, products from SEZs are mainly export-oriented, with multinational corporations (MNCs) as the main players. On the other hand, secondary industries, peripheral zone operators and secondary circuit operators (Figure 3), are mainly oriented towards local markets. Two types of market are generally identified:

*Unbalanced growth model from the SEZs specialized in the transformation of natural resources in underdeveloped regions of developing countries*



**Figure.** Unbalanced growth model based on SEZs specializing in the processing of living natural resources (Disparities analysis map and flows).

Large local markets, mainly dominated by products from the main and secondary hubs, generating very few agglomeration effects.

- Small local markets, which are generally favored by players in the secondary economic circuits identified by Milton Santos (1974).

4. **Peripheral zones:** Composed of extractive motor units and peasant productive units

Theorized for the first time by Friedman (1966) [5], and taken up by many traditional and contemporary authors, peripheral zones supply the main and secondary poles with raw materials for processing. They are mainly made up of primary resources, multinational extractive companies, subcontractors, peasant extraction activities, natural resource exploitation and, finally, peasant farming activities (Figure 3).

5. **Secondary production circuits** : *Composed of productive, commercial and industrial processing units, most of which are informal*

Secondary production circuits (Figure 3) enable the realization and development of the activities of units that are not propelled or are weakly propelled and destructured by the polarization phenomenon (destabilized, highly competitive, weakly considered by sector regulations). This circuit, known as the "Secondary Circuit", was theorized by Milton Santos (1974) [39] and taken into account by RP. Misra (1990) [40], with the theory of growth points. Local agricultural sectors in Sub-Saharan Africa are mainly made up of this type of economic agent. Local sectors are already suffering from the harmful effects of the presence of industrial firms, favored by national regulations in these countries. As developing countries pursue strategies of economic growth and industrialization through the use of SEZs, social and societal pressures and economic disparities become more pronounced. It is therefore of crucial importance to strengthen research into the control and understanding of the effects of imbalances, as well as the development of innovative tools and methods for managing these imbalances generated by SEZs in the underdeveloped regions and territories of southern countries.

## 2. Quantitative and qualitative evaluation of discrepancies

The second pillar of the SEMMD is the quantitative and qualitative assessment of disparities. It uses hybrid indicators—such as industrial productivity, financial inclusion, technological absorption capacity, and the degree of economic diversification—and employs tools like DEA analysis, spatial models, and geographic information systems (GIS). This multi-level approach makes it possible to measure the intensity and evolution of disparities, to compare the effectiveness of homogeneous areas such as SEZs with that of peripheral heterogeneous areas, and to identify structural barriers to convergence.

### 3. Disparity Management

To correct these imbalances, the SEMMD then incorporates proactive rebalancing mechanisms. These levers take the form of vertical channels, such as income transfers, local subcontracting, and the dissemination of know-how and patents from central hubs to peripheral areas, as well as horizontal channels aimed at strengthening equal access to infrastructure, training, and public services through, for example, regional sovereign wealth funds and public-private partnerships. These mechanisms are complemented by territorial performance contracts that set specific targets for reducing disparities.

### 4. Feedback and Adjustment

Finally, the model relies on dynamic and adaptive management through interactive geospatial dashboards and early warning systems based on artificial intelligence, allowing policies and investments to be adjusted in real time according to the observed evolution of territorial disparities.

The SEMMD stands out for its integrated approach, combining spatial analysis, quantitative and qualitative measurements, and broad governance involving public, private, and civil society actors. Inspired by the work of Myrdal, Hirschman, and Friedman, it offers decision-makers a comprehensive strategic tool to transform areas of inequality into drivers of more inclusive and sustainable development, by continuously and differentially managing territorial dynamics .

### Conceptual improvements to the SEMMD

The SEMMD model presents several major conceptual improvements. First, it offers a detailed, multi-level territorial segmentation through a typology of six functional zones, enabling a more precise analysis of development gradients and the dynamics between formal, informal, central, and peripheral areas. Second, it integrates hybrid indicators, combining quantitative data (such as spatial Gini coefficient, FDI, and productivity) and qualitative data (such as financial inclusion and absorption capacity), thus offering a more holistic approach adaptable to diverse institutional contexts. Furthermore, the model incorporates proactive rebalancing mechanisms, inspired by Hirschman's work on spillover effects and Myrdal's work on cumulative causality, by introducing innovative corrective tools such as performance contracts and regional funds to institutionalize diffusion and redistribution flows. Finally, the SEMMD broadens stakeholder participation by

involving CSOs, local authorities, informal actors, and development banks in a polycentric governance framework, in line with Milton Santos's reflections on hybrid economies. These advances strengthen the model's relevance and effectiveness in analyzing and managing territorial dynamics.

**Conceptual Framework Table of the SEMMD Model**

Pillar	Summary description	Main objectives	Key tools and methods	References and foundations
<b>1. Spatial segmentation</b>	Typology with six economic and geographical zones (SEZs, secondary industries, logistics corridors, local markets, rural peripheral areas, informal circuits).	Identify, map and differentiate productive roles and center-periphery interactions.	- GIS and thematic mapping - Classification algorithms (k-means, clustering) - Sectoral input-output analysis	Perroux (1955) – growth poles; - Friedman (1966) – center-periphery; Milton Santos (1974) – secondary circuits
<b>2. Multi-level assessment</b>	Quantitative and qualitative measurement of territorial disparities and dynamics of integration or exclusion.	Quantify the gaps (productivity, inclusion, diversification), compare the performance of homogeneous (SEZ) and heterogeneous (peripheral) areas.	- DEA (Data Envelopment Analysis) - Spatial models (SAR, SEM) - Polarization and convergence indices ( $\beta$ , $\sigma$ , spatial Gini)	Myrdal (1957) – cumulative causality; Hirschman (1958) – cascading effects
<b>3. Management of disparities</b>	Implementation of vertical and horizontal corrective channels to sustainably reduce discrepancies.	Redistribute the positive effects of central hubs, structure center-periphery synergies, develop infrastructure and training.	- Territorial performance contracts - Regional sovereign wealth funds - Public-private partnerships for inclusive infrastructure	Hirschman (1958) – Diffusion and Enclaves: Contemporary Theories of Polycentric Governance
<b>4. Dynamic piloting</b>	Real-time monitoring and adjustment system based on up-to-date territorial and economic data.	Adapt policies and investments according to the actual evolution of the gaps.	- Interactive dashboards (GIS) - Early warning systems (AI, machine learning) - Composite indicators	Modern approaches to monitoring and smart governance

**Table. Operational framework of the SEMMD model – Systemic and dynamic approach by pillar.**

Analytical pillar	Functional component	Monitoring and impact indicators	Main mechanisms of action and tools	Key stakeholders and institutions	Timing of intervention
<b>1. Spatial Segmentation</b>	<b>Differentiated mapping of the 6 economic zones</b> (SEZs,	- Spatial polarization index (spatial Gini coefficient,	- Spatial classification algorithms (k-means,	National spatial planning agencies,	<b>T0 – Initial diagnosis phase (6 months)</b>

	secondary industries, logistics corridors, urban markets, rural peripheries, informal circuits)	Myrdal index) - Densification rate of strategic infrastructure (km/km <sup>2</sup> ) - Local transformation rate in value chains	- clustering) - Multi-criteria hierarchical analysis (HPA) via GIS	AU/UNCTAD Economic Commission	
	<b>Assignment of productive roles to zones</b>	- Ratio of FDI captured between centers and peripheries - Level of integration of local SMEs into value chains (%) - Logistics connectivity score (Logistics Performance Index)	- Sectoral input-output analysis - Gravity modeling of interregional flows	Ministry of the Economy, Chambers of Commerce, Regional Logistics Experts	<b>T0 + 6 months - Strategic framework</b>
<b>2. Quantitative Evaluation</b>	<b>Comparative evaluation of SEZs (homogeneous zones)</b>	- Industrial productivity (value added/employee) - Export rate of processed products (%) - Capital retention index (average reinvestment period)	- International benchmarking (regional comparison) - DEA (Data Envelopment Analysis) to measure relative effectiveness	Investment promotion agencies, central bank, national statistical centers	<b>T0 + 12 months - Comparative analysis</b>
	<b>Socio-economic audit of peripheral areas (heterogeneous areas)</b>	- Technological absorption capacity (normalized scale 0-100) - Financial inclusion rate - Employment-growth elasticity	- Localized field surveys - SAR (spatial autoregressive) models to identify neighborhood effects	Local authorities, civil society organizations (CSOs), local universities	<b>T0 + 18 months - Territorial development</b>
<b>3. Managing Disparities</b>	<b>Vertical center-to-periphery diffusion channels</b>	- Percentage of revenue reinvested in outlying areas - Volume of patents transferred - Local subcontracting rate of large companies	- Performance contracts between Special Economic Zones (SEZs) and peripheral regions - Modulated tax incentive systems	Multinationals, Directorate General of Finance, Regional Development Agencies	<b>Quarterly - Contractual monitoring</b>
	<b>Horizontal infrastructure equalization channels</b>	- Tax resource equalization index - Budgets invested in rural connectivity corridors - Coverage rate in adapted	- Establishment of regional sovereign wealth funds - Public-private partnerships (PPPs) for	Public Treasury, Multilateral Development Banks (AfDB, IBRD)	<b>Annual - Budget Programming</b>

		vocational training		inclusive infrastructure		
<b>4. Feedback and Adjustment</b>	<b>Dynamic territorial governance system (feedback loops)</b>	- Regional convergence index ( $\beta$ -convergence and $\sigma$ -convergence) - Variation in interregional wage gaps - Economic diversification rate (number of emerging sectors)	( $\beta$ -convergence and $\sigma$ -convergence) -	- Interactive dashboards powered by geospatial data (GIS) - Early warning systems via AI and machine learning	National Observatory of Inequalities, Central Banks, Territorial Monitoring Networks	<b>Real-time - Continuous monitoring</b>

## IV. Discussion

The analysis of the impacts of the Nkok Special Economic Zone (SEZ) on the forestry sector in Gabon highlights growth dynamics and marked regional disparities. In comparison with the international experiences presented in the literature, several trends and specificities can be identified.

### 1. Export growth and industrial production

The results of the Nkok SEZ study indicate a significant increase in exports and industrial production in the homogeneous area, with regression coefficients ranging between 84% and 97%. These effects can be attributed to economies of scale, agglomeration effects and competitive advantages similar to those observed in the Chinese (Wang 2013) [51] and Indian (Aggarwal 2012) SEZ [52]. The results obtained in Gabon show that they could reach those of Asia if the momentum is maintained over the long term. However, the Asian experiences show that the integration of African SEZs in general into global value chains remains limited, a key factor identified by Zeng (2015) [53] as inhibiting the impact of African SEZ. But the one of Gabon could be the exception if the dynamics of endogenous growth coupled with foreign trade remains maintained in the long term.

### 2. Regional disparities and polarization effects

One of the peculiarities of the Nkok SEZ is the increased economic polarization between homogeneous and heterogeneous spaces. While export revenues have strongly stimulated growth in the homogeneous space, their impact in the heterogeneous space remains much smaller. This concentration effect is similar to the studies of Farole (2011) [4]. on African EPZs, which show that their impact is often limited due to a lack of infrastructure and attractive policies. In addition, the increase in specialization in resource extraction to supply homogeneous space reflects an economic polarization process similar to the "backwash" effects observed in other studies on developing SEZ.

### 3. Macroeconomic and dynamic growth effects

Regarding the impact of export earnings, growth dynamics in the homogeneous area has a high self-regressive effect (77%-94%) on its own growth, while its influence on macroeconomic variables is still low (6%-25%) because of its recent creation (2012) but growing rapidly from year to year. Conversely, the heterogeneous space shows a lower autoregressive effect (69%-88%) but a more important influence on macroeconomic variables (8%-59%) due to its age (data: 1970 to 2022) while slowing its growth since the creation of the Nkok SWZ (data: 2012-2022). This observation highlights a structural trend in which the economic benefits of the SEZ remain concentrated in a small cluster, thus reducing their impact on the overall economic development of the country. This is in line with the findings of Johansson and Nilsson (1997) [54], which emphasize that the effect of the SEZ on industrial production is proportional to the investment in capital and infrastructure.

### 4. Particularities of the forestry sector in Gabon

The forestry sector in Gabon is distinguished by its high potential for industrial processing, made possible thanks to the policies of ban on the export of logs introduced in recent years. Unlike

other countries where the SEZ focuses on widespread industrialization (Alder, Shao & Zilibotti, 2016) [55], the Nkok SEZ is primarily aimed at developing a value chain around wood. This strategy captures greater value added at the national level, although its success still depends on improving infrastructure, diversifying value chains and integrating them into international markets.

The comparative analysis of the impacts of the SEZ shows that while the Nkok SEZ follows certain trends observed in Asian countries, its impact remains limited by some structural problems similar to those encountered in Africa. The forestry sector in Gabon is characterized by a strong orientation towards industrial wood processing, but regional disparities and low diversification are still major obstacles. To maximize the impact of the Nkok SWZ, it is essential to increase investment in infrastructure, diversify existing industries and improve attractiveness for international investors.

## V. Limitations of the Study and Future Research Prospects

This research assessed the impact of the Nkok SEZ on the forestry sector, based on industrial and commercial indicators, while highlighting regional disparities and the mechanisms underlying the endogenous growth of this sector in Gabon over the period 2014-2022. However, some limitations remain.

The first limitation concerns the relatively short duration of the time series used (2014-2022), due to the recent creation of the SEZ in 2012. This restricts the ability to analyze long-term effects and limits the scope of the results obtained. For a more in-depth assessment, longer data series, ideally covering nearly 30 years, would be necessary. The application of ARDL (Auto-Regressive Distributed Lag) models could allow a joint analysis of short- and long-term effects.

The second limitation is that the study focuses only on the Nkok SEZ, without including other special economic zones. Integrating several SEZs into the analysis would provide more comparative data and enrich the conclusions. A study conducted in a developing country with several SEZs would allow the use of parametric models to identify new factors influencing their effectiveness. An approach based on extended panel data would provide a more complete view of the endogenous growth dynamics induced by SEZs and would allow the development of policies better adapted to the realities of developing countries.

For future research, it would be relevant to deepen the analysis of the effects of SEZs on economic development and regional disparities, with a focus on countries in the South, particularly in sub-Saharan Africa. These studies should explore existing imbalances, assess the impact of SEZs, compare internal and external disparities, and propose decision-making tools to better manage polarization dynamics. They could also contribute to strategic planning and governance of regional growth induced by SEZs. The models of regional imbalances developed in this future work should shed light on the processes of economic and spatial polarization in developing regions. In addition, this research should identify the mechanisms underlying economic and geographic polarization, analyze the inequalities it generates, and formulate strategies to mitigate these imbalances, while promoting more harmonious and inclusive development.

## VI. Political Implications

The conclusions drawn from the evolution of the Nkok SEZ between 2014 and 2022 highlight key economic dynamics for the development of public policies.

### 1. Strengthening industrial and export strategies

The positive impact of the Nkok SEZ on export income highlights the importance of encouraging the creation of specialized economic zones (SEZs) as development tools. To maximize their effectiveness, public policies should promote strategic investments and develop infrastructure that facilitates the local processing of raw materials, in order to increase the added value of exports.

### 2. Regulation and optimization of the supply of raw materials

The decrease in export volumes, due to restrictions on wood resources and export bans on unprocessed raw materials, highlights the need for more sustainable and planned management of

forest resources. To ensure a stable supply to local industries while preserving ecosystems, policymakers must strengthen regulatory frameworks for forest exploitation and management.

### **3. Promotion of local processing and diversification of products**

The development of processing processes and the diversification of wood forest products, particularly in furniture and secondary processing, show that public policies must further support local industrialization. Incentives, such as tax breaks, support for processing companies and the promotion of innovation in the wood sector, would be beneficial to accelerate this dynamic.

### **4. Territorial rebalancing of industrial development**

The organization of the economic space into homogeneous and heterogeneous zones reveals a concentration of investments around the Nkok SEZ, leading to uneven development. To address these disparities, public policies should aim for more balanced territorial planning by encouraging the creation of other regional industrial hubs, in order to better distribute economic and social benefits at the national level.

### **5. Support for value chains and investment attractiveness**

The close relationship between increasing industrial income and local processing highlights the need to structure and strengthen industrial value chains. To attract more investment and increase the competitiveness of the forestry sector, public authorities should facilitate access to financing, improve worker training and develop appropriate infrastructure.

## **Conclusion**

The challenges related to understanding the spatio-temporal developments of global centers are pushing industrialized and emerging countries to develop research and monitoring strategies to anticipate their impacts on value chains. These efforts contrast with the difficulties of developing countries, which lack specialized tools to plan and monitor these changes. Regional imbalances, particularly linked to special economic zones (SEZs), aggravate socio-economic disparities. In this context, it is crucial to analyze how certain countries in Asia, South America and Africa have managed their SEZs to promote development while limiting disparities, and to measure the evolution of these imbalances to better understand and mitigate them.

This study made it possible to aim for two main objectives, the first objective is to empirically study the influence of the Nkok special economic zone on the forestry sector in Gabon and to compare regional disparities between the homogeneous space (inside the Nkok SEZ) and the heterogeneous space (outside the Nkok SEZ). The second objective is to try to explain the mechanisms behind endogenous growth and those behind the disparities in the forestry sector in Gabon.

Concerning internal disparities, export revenues in the homogeneous space, between 2014 and 2022 have significantly stimulated the growth of exports and industrial production of forest products. The regression coefficients show increases ranging from 84% to 97%. These effects are attributed to competitive advantages, economies of scale and agglomeration effects, although this reinforces disparities with heterogeneous space. Whereas in the heterogeneous space, export revenues had much weaker effects on the growth of exports and industrial production during the same period. Concerning external disparities, they are amplified by negative market mechanisms ("backwash" effects) and increased specialization in the extraction of resources to supply the homogeneous space, reflecting a process of polarization. Regarding the impact of income on the macroenvironment, the homogeneous space influences export income by having a high autoregressive impact (77%-94%) on their own growth and weakly influences macro-environmental variables (6%-25%). While for the influence of the heterogeneous space, the autoregressive effect is weaker (69%-88%) and the macro-environmental variables are affected more strongly (8%-59%) than those of the homogeneous space. However, the dynamic growth remains stronger in the homogeneous space. Overall, regional disparities are reinforced by the growing predominance of homogeneous space in industrial processing and exports, to the detriment of heterogeneous space.

## Appendix A. Modeling of internal imbalances

### Estimation by "OLS (Robust)" method

**Table A1.** Estimates of the effects of export revenues in homogeneous space.

variable	Model 1	Model 2	Model 3	Model 4
	<b>Export Income</b>			
Forestry Exports	0.929*** (0.090)			
Industrial Forestry Production		0.968*** (0.082)		
Saw timber industrial production			0.956*** (0.022)	
Industrial production of veneer wood				0.841*** (0.089)
Constant	-6,670*** (1.069)	-7.208*** (0.982)	-6,227*** (0.242)	-5.052*** (1.002)
Comments	9	9	9	9
On R-squared	0.939	0.952	0.996	0.927

Standard error in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

**Table A2.** Estimates of the effects of export revenues in heterogeneous space.

variable	Model 1	Model 2	Model 3	Model 4
	<b>Export Income</b>			
Forestry Exports	0.376 (0.322)			
Industrial Forestry Production		0.372* (0.171)		
Saw timber industrial production			-0.076 (0.261)	
Industrial production of veneer wood				0.032 (0.065)
Constant	0.525 (4.824)	0.773 (2.482)	7.163* (3.496)	5,770*** (0.788)
Comments	9	9	9	9
On R-squared	0.163	0.404	0.014	0.033

Standard error in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

## Appendix B

### Estimation by method "Fixed Effect-Bias-Corrected Estimation (Robust)"

**Table B1.** Estimates of the effect of homogeneous space on the macroenvironment.

	Model 1	Model 2	Model 3	Model 4
Independent variable	Forestry Exports	Industrial Forestry Production	Saw timber industrial production	Industrial production of veneer wood
	<b>Export Income</b>			
$\Delta$ . Export Income	0.768*** (0.053)	0.836*** (0.016)	0.841*** (0.012)	0.841*** (0.037)
Forestry Exports	0.250			

	(0.248)			
Industrial Forestry Production		0.152		
		(0.218)		
Saw timber industrial production			0.060**	
			(0.029)	
Industrial production of veneer wood				0.067***
				(0.011)
Constant	-2.249	-1.169	0.258	0.207
	(3.427)	(3.126)	(0.467)	(0.371)
(N/T)	60/2	60/2	60/2	60/2
Autocorrelation order 1	-1.086	-1.0560 (0.291)	-1.0575 (0.290)	-1.161 (0.245)
Autocorrelation order 2	(0.277)	1.1642 (0.244)	1.023 (0.306)	1.311 (0.189)
	1.006			
	(0.237)			

Robust standard error in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

**Table B2.** Estimates of the effect of heterogeneous space on the macroenvironment.

	Model 1	Model 2	Model 3	Model 4
Independent variable	Forestry Exports	Industrial Forestry Production	Saw timber industrial production	Industrial production of veneer wood
Export Income				
$\Delta$ . Export Income	0.696***	0.804***	0.856***	0.877***
	(0.000)	(0.001)	(0.004)	(0.001)
Forestry Exports	0.597***			
	(0.002)			
Industrial Forestry Production		0.538***		
		(0.008)		
Saw timber industrial production			0.079***	
			(0.004)	
Industrial production of veneer wood				0.077***
				(0.000)
Constant	-7.067***	-6.672***	-0.119***	-0.143***
	(0.027)	(0.118)	(0.034)	(0.004)
(N/T)	60/2	60/2	60/2	60/2
Autocorrelation order 1	-1.019	-1.021 (0.307)	-1.020 (0.307)	-1.097 (0.272)
Autocorrelation order 2	(0.308)	1.025 (0.305)	1.2905 (0.196)	1.065 (0.286)
	1.181 (0.314)			

Robust standard error in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

The assumption of the Arellano-Bond test for the autocorrelation of the residuals in first order and second difference are : "H0: no autocorrelation of order 1 or 2". The *p*. values are in parentheses and Z statistics are outside parentheses.

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