External Debt and Manufacturing Sector's Performance in MINT Countries: Evidence from Dynamic Heterogeneous Panel Estimation Techniques

Nurudeen Abu[1], Joseph David[2], and Musa Abdullahi Sakanko[3]

Abstract

The study assesses external debt's impact on MINT countries' (Mexico, Indonesia, Nigeria, and Türkiye) manufacturing sector's performance during the 1980-2021 period, using dynamic heterogeneous panel methods (i.e., Dynamic Fixed Effects, Mean Group, and Pooled Mean Group estimators). The findings portray presence of long-term relation between external debt and manufacturing performance (alongside external debt service, inflation rate, population size, exchange rate, FDI, and agricultural output) based on the Kao's residual cointegration test. The empirical outcomes portray a dampening impact of external debt on manufacturing sector's performance during the short- and long-term. Moreover, external debt servicing, FDI, population size, and inflation rate promote the sector's performance, but exchange rate (depreciation) hurts manufacturing performance. Furthermore, the Dumitrescu-Hurlin heterogeneous panel causality test portrays a one-way causality from external debt servicing (and exchange rate) to manufacturing sector's performance, and a two-way causality between manufacturing sector and population (and FDI, and agricultural output). Thus, policies aimed at lowering external debt, lessening exchange rate variability and inflation rate, and boosting inward FDI are recommended to promote the sector's performance.

Keywords: Manufacturing sector, external debt, MINT countries, dynamic panel technique
JEL Codes: C23, C33, L60, N60, F34, H60

1. Introduction

The significance of the manufacturing sector in the economic development process can't be overstressed. The newly emerging group comprising Mexico, Indonesia, Nigeria, and Türkiye (i.e., MINT) was coined in line with the nations' potential as manufacturing hubs and investment destinations. For example, Mexico has a strong manufacturing sector, particularly in industries like automotive, electronics, and aerospace (Ibarra, 2024; World Bank, 2024), which account for a significant share of its GDP and exports. However, Mexico's manufacturing sector faces challenges such as high labor costs, reliance on the U.S. market, and the need for technological upgrades to maintain competitiveness (Casalet, 2023). Indonesia has seen considerable growth in its manufacturing sector, with industries like textiles, electronics, and automotive contributing to economic expansion (IMF, 2021; Handoyo et al., 2024). Despite this growth, Indonesia's manufacturing sector contends with problems like inadequate infrastructure, regulatory hurdles, and a shortage of skilled labor (Budiono et al., 2021).

Furthermore, Nigeria has also sought to diversify its economy by developing its manufacturing sector, with a focus on agro-processing, textiles, and cement (World Bank, 2019). These efforts to promote industrialization and diversify the economy beyond oil have evidently raised the potential of industries such as cement, food processing, and textiles as crucial to Nigeria's economic development (Awe et al., 2023; Ogbonna et al., 2021). However, despite policy initiatives, the

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[1] Baba Ahmed University, Kano – Nigeria
[2] Lagos Business School, Pan-Atlantic University, Lagos – Nigeria
[3] University of Jos, Jos – Nigeria

country's manufacturing sector continues to face significant structural challenges, including inadequate infrastructure, policy uncertainties, limited access to finance, exchange rate fluctuations, and frequent power outages (Oyewumi et al., 2020; Wolf, 2023). Türkiye boasts a well-established manufacturing base, with strengths in automotive, machinery, and textiles (Cakir et al., 2024; Central Bank of the Republic of Türkiye, 2021; OECD, 2021; Özgüner et al., 2023). Besides its significant role in job creation and its contribution to the country's export earnings (Turkish Statistical Institute, 2021; Özgüner et al., 2023), the Turkish manufacturing sector is increasingly adopting green technologies and sustainable practices, which have helped improve its competitiveness in European markets (Yıldız et al., 2023). Despite these advancements, Türkiye's manufacturing sector still grapples with issues of productivity and the need for deeper structural reforms (Cakir et al., 2024).

Besides, the MINT nations have also experienced varying levels of external debts over the years. Nigeria, for instance, is currently faced with substantial external debt burden due to oil price volatility, fiscal mismanagement, and corruption (Abu et al., 2022a, 2022b; David et al., 2024; Iyoha & Oriakhi, 2019). The country has implemented debt relief programs and pursued economic diversification to reduce its dependence on oil revenues (Abu et al. 2022a, 2022b; Onapajo & Balogun, 2018). Notwithstanding, the county's external debt has increased in recent years, driven by the need to finance infrastructure projects and address fiscal challenges (Central Bank of Nigeria, 2021, 2022 Oyadeyi et al., 2024). Similarly, Indonesia also has a significant external debt, due largely to infrastructure investments (Ananda & Fahreza, 2024; Hartadi & Hidayat, 2020; Nazamuddin et al., 2022; Warr, 2019). The government has implemented measures to manage its external debt, including diversifying funding sources and focusing on long-term debt (Ananda & Fahreza, 2024; Bank Indonesia, 2021). Moreover, Türkiye has faced challenges with external debt sustainability, and its high external financing needs have raised concerns (Güneş & Akın, 2023; IMF, 2021; OECD, 2021; Orazgani, 2020; Shah et al., 2024). In addition, Mexico's external debt has been influenced by fiscal deficits and currency depreciation (Cornejo & Schmidt-Hebbel, 2017; Mishkin, 2017; Simionescu & Cifuentes-Faura, 2023). In the 1980s, the country faced a debt crisis that led to restructuring its external obligations (Ruíz, 2017). However, in recent years, Mexico's external debt has remained relatively stable (Shah et al., 2024).

The role of external debt on manufacturing sector's output or performance is a complex one (Hofman & Ma, 2020). For instance, external debt can provide financing for infrastructure development, technology transfer or adoption or upgrades, research and development, human capital development, market expansion, and counter-cyclical policies (Adams & Cuevas, 2019; Dudley, 2018; Manasse & Turrini, 2020; Sorensen et al., 2020). These can enhance manufacturing capabilities and productivity, competitiveness, market access, and export revenues via improved energy systems, transportation and telecommunication networks, trade promotion activities, diversification of customers' base, lower production costs, and efficient supply chain (Dudley, 2018; Duramany-Lakkoh et al., 2021; Foster et al., 2018; Krugman et al., 2021; Tiwary & Paul, 2023; World Bank, 2024). Thus, external borrowing can enable MINT nations' manufacturing sector to acquire advanced technologies and expertise amongst others, leading to increased efficiency, improved product quality, and enhanced competitiveness in global markets (Abidin et al., 2021; Tiwary & Paul, 2023), and consequently growth of the sector (Berr et al., 2021).

Nevertheless, high debt levels can also pose some challenges. For example, debt servicing obligations tend to limit fiscal space for investment in the manufacturing sector (Abidin et al., 2021; Aguiar, 2024). In addition, huge debt and uncertainty surrounding debt sustainability can crowd-out private investment, reduce fiscal space to support the manufacturing sector and its growth, thus,

causing exchange rate vulnerabilities (Abidin et al., 2021; Akkemik & Turhan, 2019; Ghosh, 2018; IMF, 2019; Sowunmi, 2018). Moreover, exchange rate vulnerabilities and uncertainty stemming from external debt can result in low competitiveness of manufacturing exports and erosion of investors' confidence (Dong et al., 2021; Sowunmi, 2018). Other consequences of rising and unsustainable external debt levels are reduction in inward FDI and allocation of a significant portion of a nation's revenue to servicing debt. These in turn limit manufacturing sector's access to capital for productive investment, technology, and global markets (Celasun et al., 2017; World Bank, 2019), leading to declines in manufacturing sector's output or performance.

In light of this, it is crucial to examine the specific impact of external debt on the performance of the manufacturing sector in the four MINT countries. The analysis of the relationship between external debt and manufacturing sector performance is particularly important due to the sector's pivotal role in fostering economic diversification and enhancing a country's global competitiveness (Awe et al., 2023). As external debt can either support or hinder manufacturing growth, depending on its use and management, understanding its effects is vital for shaping future economic outcomes. An empirical investigation of the nature of relationship between external debt and the manufacturing sector in MINT countries will provide valuable insights for policymakers and investors, highlighting factors that could either strengthen or weaken competitiveness. These insights are crucial for promoting sectoral diversification, which in turn reduces dependence on single industries like oil or agriculture. Policymakers can also use this understanding to design strategies that not only attract investment into the manufacturing sector but also ensure that external debt is managed sustainably. Furthermore, by understanding the dynamics of the impact of the external debt on manufacturing, MINT countries can better design long-term policies that balance borrowing with productive investments. This balance is essential for driving industrial development while avoiding pitfalls such as currency depreciation, inflation, or economic instability that can result from unsustainable debt levels. Ultimately, a clear understanding of how external debt affects the manufacturing sector will guide governments in making sound financial decisions, supporting sustainable sectoral growth, enhancing global competitiveness, and ensuring overall economic resilience.

This study seeks to contribute to the extant literature in several ways. First, the research is a pioneering effort to evaluate the impact of external debt (stock and servicing) on the performance of the manufacturing sector in MINT counties. The choice of MINT is based on their uniqueness and shared similarity in terms of economic potentials, debt burden, and opportunity for investment. Second, to obtained robust conclusion on the influence of external debt on the performance of the manufacturing sector in MINT nations, the research employs dynamic heterogeneous panel estimation techniques, including the dynamic fixed effects (DFE), mean group (MG), and pooled mean group (PMG) estimators. Amongst other things, the techniques accommodate both dynamic short- and long-term estimates, and a possible heterogeneous dynamic adjustment process, thus, yielding better insights on the relationship between external debt and manufacturing sector's performance. Also, the application of Dumitrescu-Hurlin heterogeneous panel causality tests provides an opportunity to understanding the direction of causality between the variables.

The remainder of the paper is structured as follow. The gap in the literature is outlined in the next subsection. Section two presents a review of the literature. Section three contains the methodology and data. The results are presented and discussed in the fourth section. The conclusion and policy recommendation are provided in the last section.

1.2 Literature Gap

While the relationship between external debt and economic performance has been widely studied, particularly in the context of growth, investment, and financial development (Aladejare, 2023; Dawood et al., 2024; Dey & Tareque, 2020; Roy, 2023; Sandow et al., 2022), there remains a significant gap in understanding how external debt specifically influences the manufacturing sector across emerging economies. Existing studies primarily focus on the impact of external debt on macroeconomic indicators such as GDP growth, fiscal deficits, and exchange rate volatility (Abdelaziz et al., 2019; Edo et al., 2020). However, few studies directly examine how external debt, especially its stock and servicing components, affects sectoral performance, particularly in the manufacturing sector, which is crucial for industrialisation and economic diversification. Moreover, while there have been studies exploring the influence of external debt on the performance of manufacturing sector at the country level—such as in Pakistan (Ayyoub et al., 2012), Nigeria (Osu, 2019), and Sierra Leone (Duramany-Lakkoh et al., 2021)—there is limited cross-country analysis that captures the heterogeneity and dynamics within emerging economies like the MINT nations. These countries, characterised by their potential as future manufacturing hubs and facing significant external debt burdens, are yet to be comprehensively analysed in the context of debt-manufacturing sector performance relationships.

Additionally, existing studies report mixed results regarding the external debt-manufacturing sector nexus, with some studies finding positive impacts of debt financing on manufacturing (Ayyoub et al., 2012; Chukwu et al., 2023; Osu, 2019; Nteegah & Olubiyi, 2022) and others highlighting its negative consequences due to crowding out of investment and exchange rate vulnerabilities (Kur et al., 2021; Matelis, 2014; Ojeka & Simon-Oke, 2023; Sowunmi, 2018). Some studies confirmed tha the influence of external debt on the performance of manufacturing sector is insignificant (Duramany-Lakkaoh et al., 2021; Mohammed & Ibrahim, 2022). This inconsistency underscores the need for more robust methodologies and broader cross-country studies to better understand the conditions under which external debt may support or hinder manufacturing sector growth. Furthermore, no prior studies have explored the external debt-manufacturing performance nexus specifically for the MINT countries, despite their strategic importance in global manufacturing supply chains and their growing external debt challenges. This research aims to fill this gap by evaluating the influence of external debt (stock and servicing) on the performance of the manufacturing sector in the four MINT countries during the 1980-2021 period, using robust estimation techniques.

2 Literature Review

The literature suggests that external debt can impact a nation's manufacturing sector's performance. Mounting and unsustainable debts hurt the manufacturing sector via causing exchange rate vulnerabilities, reducing global competitiveness and export revenues, limiting businesses' access to credit and crowd-out private investment, creating uncertainty and eroding investors' confidence (Abidin et al., 2021; Akkemik & Turhan, 2019; Celasun et al., 2017; Dong et al., 2021; Ghosh, 2018; IMF, 2019; Sowunmi, 2018; World, 2019). These in turn result to lowering manufacturing sector's performance. However, external debt can boost manufacturing sector capacity and output via increased access to finance for infrastructure development (such as transportation and telecommunication networks), technology transfer or adoption, human capital development, promotion of trade activities, market expansion, and counter-cyclical policies, amongst others (Adams & Cuevas, 2019; Dudley, 2018; Duramany-Lakkoh et al., 2021; Foster et al., 2018; Krugman et al., 2021; Manasse & Turrini, 2020; Sorensen et al., 2020; World Bank, 2021).

On the empirical front, several studies have been conducted to explore the determinants of external debt as well as the macroeconomic implications of debt (broadly) or external debt (including external debt stock and servicing) in both developed and developing economies. For instance, some studies have examined the factors influencing the performance of the manufacturing sector in emerging and developing economies (Azolibe, 2021; Lartey & Nigatu, 2021; Neoh & Lai, 2021; Onodje & Farayibi, 2020; Orji & Ezeanyaeji, 2022). The existing literature demonstrates that macroeconomic factors such as remittances, public expenditure, access to credit, foreign direct investment (FDI), interest rates, inflation, exchange rates, household expenditure, financial development, economic uncertainty, and trade liberalization play significant roles in influencing the performance of the manufacturing sector. Moreover, studies have also explored the impact of external debt on a range of factors, including sustainable economic growth and development (Aladejare, 2023; Dawood et al., 2024; Dey & Tareque, 2020; Edo et al., 2020; Guei, 2019; Mohsin et al., 2021; Roy, 2023; Sandow et al., 2022; Senadza et al., 2018), investment (Abdelaziz et al., 2019), financial development (Agyapong & Bedjabeng, 2020), infrastructural development (Ariyibi et al., 2023; Kengdo et al., 2020), remittance outflows (Mijiyawa & Oloufade, 2023), and carbon emissions (Bachegour & Qafas, 2023; Bese et al., 2021; Carrera & de la Vega, 2024). The conclusions on the influence of external debt on these macroeconomic factors are generally mixed, with conflicting outcomes.

However, there is a noticeable dearth of empirical studies on the relationship between external debt (stock and servicing) and the performance of the manufacturing sector, both from a country-specific and cross-country perspective. Furthermore, despite presenting conflicting conclusions on the nature of the relationship between external debt and manufacturing sector performance, most of the existing studies focus on developing economies. For example, Ayyoub et al. (2012) employed the ordinary least squares (OLS) estimator to investigate the influence of external debt stock and debt servicing on the growth of the manufacturing sector during the 1989-2010 period in Pakistan. The results demonstrate that external debt has a significant positive influence on the performance of the manufacturing sector. However, the results suggest that debt servicing has an adverse influence on manufacturing sector output growth. In addition, Osu (2019) used both the OLS estimator and the Granger causality test method to explore the impact of external capital flows (which include external debt, FDI, and foreign portfolio investment) on the performance of the manufacturing sector between 1980 and 2017. The results confirmed a strong positive influence of external debt on the manufacturing sector's performance.

Furthermore, studied the impact of external debt, trade openness, exchange rates, and FDI on the performance of the manufacturing sector in Nigeria during the 1985-2020 period. Using the vector error correction model (VECM), the results demonstrate the significant positive influence of external debt on the performance of the manufacturing sector in the short term. From a multi-country perspective, Chukwu et al. (2023) employed the fully modified ordinary least squares (FMOLS) estimator to explore the role of institutions in influencing the effect of external debt on the industrial sector in 17 emerging economies (including Nigeria) between 2005 and 2018. The results reveal that external debt and government effectiveness have a strong positive impact on the performance of the industrial sector, while the simultaneous increase in external debt, alongside reduced corruption, a stable political environment, improved rule of law, and regulatory quality, supports the industrial sector's performance.

Contrarily, some studies report an adverse impact of external debt on the performance of the manufacturing sector. For example, Matelis (2014) used the dynamic system generalised method of moments (SYS-GMM) technique to investigate the impact of external debt on the manufacturing

sector in 12 Union of South American member countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela) between 1980 and 2011. The findings reveal the negative impact of external debt stock on manufacturing sector performance. Kur et al. (2021) investigated the influence of external debt stock and servicing on sectorial performance in Nigeria and Botswana between 1981 and 2019 using the autoregressive distributed lag (ARDL) bounds-testing technique. The results show that external debt stock has a strong adverse impact on the short- and long-term performance of the industrial sector, while external debt servicing stimulates industrial sector performance in both countries. In addition, Ojeka and Simon-Oke (2023) employed the ARDL bounds-testing technique alongside the vector autoregressive (VAR) impulse response function to study the influence of external debt on Nigeria's industrial sector growth between 1985 and 2019. The results reveal that external debt stock and servicing have a strong negative influence on industrial sector growth.

Moreover, some studies have confirmed that the influence of external debt on manufacturing sector performance is insignificant. For instance, Duramany-Lakkaoh et al. (2021) examined the short- and long-term determinants of the manufacturing sector's performance in Sierra Leone between 1970 and 2018 using the Vector Auto Regression (VAR) technique. The results conclude that the impact of external debt stock on manufacturing sector performance is negative but statistically insignificant. Similarly, Mohammed and Ibrahim (2022) employed the autoregressive distributed lag (ARDL) bounds-testing technique to examine the external determinants of manufacturing sector performance in Nigeria during the 1981-2021 period. The results demonstrate the insignificance of external debt stock in stimulating Nigeria's manufacturing sector performance.

Evidence of a non-linear relationship between external debt and industrial sector performance has also been presented in the literature. For instance, Fogang and Tchitchoua (2020) investigated the effect of external debt on industrial sector performance amidst non-linearity in 10 countries in the African franc zone between 1996 and 2017. Employing the panel smooth transition regression (PSTR) approach, the results reveal a non-linear relationship between external debt and industrial sector performance, with the impact of external debt depending on the level of external debt stock. Before the identified threshold point, external debt has no significant impact on industrial sector performance, but after the threshold point, external debt becomes detrimental to industrial performance. Additionally, findings based on the generalized least squares (GLS) and seemingly unrelated regression (SUR) estimators suggest that external debt stimulated industrial sector performance before 2006 but hindered it after 2006.

Based on the surveyed literature, three conclusions can be drawn. First, despite the extensive research on external debt and other potential drivers of manufacturing sector performance, limited attention has been given to understanding the impact of external debt on the manufacturing sector at both country-specific and cross-country levels. Second, existing research presents mixed findings on the relationship between external debt and the manufacturing sector. Third, studies examining this relationship are absent in MINT countries, despite their manufacturing potential and current debt challenges. Therefore, this research contributes to the literature by evaluating the impact of external debt (stock and servicing) on the manufacturing sector in MINT nations from 1980 to 2021, employing robust estimation techniques such as DFE, MG, and PMG.

3 Methodology and Data
3.1 Model Specification
To explore external debt impact on MINT countries' manufacturing sector, the study specifies the model:

$$MAN_{it} = \omega_1 EXD_{i,t} + \delta' Z_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \tag{1}$$

where $i = 1,2,...,N$ is the number of countries, and $t = 1,2...,T$ denotes time. ω_1 and δ are slope coefficients. MAN represents manufacturing sector performance (proxy by manufacturing sector value-added in US dollars), and EXT is external debt stock (proxy by ratio of total external debt stocks to gross national income). Z is a set of control variables including debt service on external debt in US dollars, official exchange rate (proxy by annual average based on of yearly averages of local currency units relative to the US dollar), total population, foreign direct investment relative to the GDP, annual inflation rate, and agricultural output relative to the GDP). μ_t is unobserved time-specific effect, η_t represents country-specific effect, and $\varepsilon_{i,t}$ is independent and identically distributed error term. Except inflation rate, external debt, foreign direct investment, and agricultural output, all other variables are log transformed before analysis to reduce skewness. The data on all variables are sourced from the World Bank's World Development Indicators (WDI) database. Annual data used covers the 1980-2021 period. A summary of the description, a priori expectation, and source of data of all the variables (including the control variables) is provided in Table 1.

Table 1 Description of variables

Variable	Description	Source	Expected effect
Manufacturing output (MAN)	MAN is the net output of the manufacturing sector without making adjustments for depreciation of fabricated assets or depletion and degradation of natural resources. The data is in current U.S. dollars.	World Bank	–
External debt stock (EXD)	EXD is the ratio of total external debt stocks to gross national income. Total external debt includes all public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt owed to nonresidents repayable in currency, goods, or services.	World Bank	Negative
Debt servicing ($DSER$)	$DSER$ is the sum of principal repayments and interest paid in currency, services, or goods on long-term debt, interest paid on short-term debt, and repayments (repurchases and charges) to the IMF. The data is in current U.S. dollars.	World Bank	Negative
Exchange rate ($EXCH$)	$EXCH$ is the annual average of local currency units relative to the U.S. dollar.	World Bank	Negative
Population (POP)	POP is the midyear estimate of the total population number of residents (regardless of legal status or citizenship) in a territory.	World Bank	Positive
Foreign direct investment (FDI)	FDI is the ratio of net FDI inflows to the GDP. FDI is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments.	World Bank	Positive
Inflation rate (INF)	INF is measured by the consumer price index (CPI) which reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly.	World Bank	Negative

Agricultural output (AGR)	AGR is the ratio of the value added of forestry, hunting, fishing, and cultivation of crops and livestock production to the GDP.	World Bank	Positive

Notes: WDI represent the World Bank's World Development Indicators.

3.2 Estimation Technique

Having the length of time-series (T) greater than the number of countries (N), the research employs Dynamic Fixed Effects (DFE), Mean Group (MG) and Pooled Mean Group (PMG) estimators. Although similar, the techniques vary in their treatment of the slope coefficients. For instance, the PMG technique (Pesaran et al., 1999) assumes homogeneous long-term coefficients across groups, but allows the intercept, short-run slope coefficients, and error variance to vary across groups. In the MG technique (Pesaran & Smith, 1995), the intercept, short- and long-term slope coefficients, and the error variance are permitted to vary across countries. In contrast, the DFE estimator allows the intercept to differ across groups but assumes homogeneity of the short- and long-term slope coefficients. Generally, the techniques are favoured over the conventional methods due to their ability to accommodate long-term equilibrium and possible heterogeneous dynamic adjustment process (Ehigiamusoe & Lean, 2018; Sakanko et al. 2024).

Following Pesaran et al. (1999), a bivariate unrestricted error-correction representation of autoregressive distributed lagged (ARDL) (p,q) model is written as:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \vartheta'_{ij} x_{i,t-j} + \mu_i + v_{i,t} \tag{2}$$

where x_{it} is a $k \times 1$ vector of independent variables. ϑ_i are the $k \times 1$ coefficient vector. λ_{ij} are scalars. $v_{i,t}$ denotes the error term.

Equation (2) can be re-parameterised and expressed in an error-correction representation as:

$$\Delta y_{it} = \phi_i \left(y_{i,t-1} - \theta'_i x_{it} \right) + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \vartheta'^*_{ij} \Delta x_{i,t-j} + \mu_i + v_{i,t} \tag{3}$$

where Δ represents the first difference operator. ϕ_i is the coefficient of the error-correction term, and measures the speed of adjustment to long-term equilibrium, and θ'_i represents the vector of long-term parameters. The optimal lag length (p,q) is determined by the AIC. Since the DFE estimator assumes homogenous slope coefficients, it is used as the benchmark model while the Hausman test of homogeneity of long-term coefficients is done to assess the preferred model between MG and PMG estimators.

4 Results and Discussion
4.1 Summary Statistics and Correlation Analysis

The descriptive statistics for variables (Table 2) portray average of log of manufacturing output, external debt (% of GNI), log of external debt servicing, log of exchange rate, log of total population, FDI (% of GDP), inflation rate, and agricultural output (% of GDP) during the 1980-2021 period as 24.581 (US$76.2 billion), 42.622 percent, 23.226 (US$24.5 billion), 2.759 (1739.185/US$1), 1.415 percent, 22.507 percent, and 14.242 percent, respectively. Their corresponding standard deviations portray a wide variation in the data point. Further, the correlation analysis shows a weak but significant negative correlation between manufacturing sector output and external debt (and inflation rate). Also, a weak positive correlation exists between manufacturing

sector output and exchange rate (and population, and FDI), but a strong negative correlation between agricultural output and manufacturing sector. Moreover, the correlation between external debt service and manufacturing sector is strong, positive and significant.

Table 2 Descriptive statistics and correlation matrix

	lnMAN	*EXD*	*lnDSER*	*lnEXCH*	*lnPOP*	*FDI*	*INF*	*AGR*
Mean	24.581	42.622	23.226	2.759	18.023	1.415	22.507	14.242
Std. dev.	1.051	22.788	1.357	4.544	0.516	1.176	26.120	8.031
Min.	24.562	39.622	23.455	2.528	17.954	1.364	10.454	14.133
Max.	26.162	168.198	25.190	9.588	19.038	5.791	131.827	36.965
lnMAN	1.000							
EXD	-0.221***	1.000						
lnDSER	0.854***	0.121*	1.000					
lnEXCH	0.221***	0.127*	0.134*	1.000				
lnPOP	0.342***	0.056	0.217***	0.956***	1.000			
FDI	0.366***	-0.059	0.293***	0.153**	0.134*	1.000		
INF	-0.355***	0.279***	-0.198***	-0.557***	-0.566***	-0.199***	1.000	
AGR	-0.780***	0.044	-0.799***	0.179**	0.138*	-0.330***	0.044	1.000

Note: MAN = ratio of manufacturing output to GDP; EXD = external debt stock (% GNI); EXCH = official exchange rate; POP = total population (ages 15-64); FDI = foreign directing investment inflow (% of GDP); INF = inflation rate (%); AGR = Agriculture, forestry, and fishing, value added (% of GDP). *ln* denotes natural log. Asterisks (***), (**) and (*) denotes statistical significance at 1%, 5% and 10% levels, respectively.

4.2 Cross-sectional Test

To determine the presence of cross-sectional dependence amongst MINT nations, four cross-section dependence (CSD) tests are conducted (Breusch-Pagan LM, Pesaran scaled LM, Pesaran CSD, and Baltagi-Feng-Kao Bias-corrected Scaled LM). The results of the CDS tests (Table 3) portray that null hypothesis of "no cross-sectional dependence" is rejected for all variables, thus, indicating the presence of interdependence amongst the nations.

Table 3 Results of Cross-sectional Dependence Tests

CSD Tests/Variables	Breusch-Pagan LM	Pesaran scaled LM	BFK bias-corrected scaled LM	Pesaran CD
lnMAN	150.273***	41.648***	41.599***	11.789***
EXD	18.984***	3.748***	3.699***	2.023**
lnDSER	106.629***	29.049***	29.0004***	8.179***
lnEXCH	226.712***	63.714***	63.665***	15.049***
lnPOP	249.884***	70.403***	70.355***	15.808***
FDI	20.788***	4.269***	4.219***	3.337***
INF	22.462***	4.752***	4.703***	3.589***
AGR	140.622***	38.862***	38.813***	3.035***

Note: H_0: no cross-section dependence (correlation). $df = 6$. Asterisks (**) and (***) denote significance at the 5% and 1% level, respectively. BFG is Baltagi, Feng and Kao (2012) Bias-corrected Scaled LM CSD test.

4.3 Panel Unit Root Test

Also, the results of unit root tests (Table 4) using both the first-generation panel unit root tests (Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and ADF-Fisher tests, and the second-generation test (Pesaran, 2007 CIPS test) present mixed outcomes. For instance, the first-generation tests suggest that debt servicing, exchange rate, FDI, inflation rate, agricultural output are integrated to order zero, while manufacturing sector output and external debt and population are integrated at

order 1. However, the results of Pesaran (2007) test (which account for cross-sectional dependence) portray that all variables (except debt service and population) are stationary at level.

Table 4 Panel Unit Root Tests

Variables/Tests	First generation tests			Second generation test
	LLC	IPS	ADF-Fisher	CIPS
lnMAN	-0.817	1.431	2.368	-2.413**
EXD	-0.736	-1.093	10.728	-2.330**
lnDSER	-3.095*	-1.131**	15.115***	-1.736
lnEXCH	-4.829***	-3.210***	30.843***	-3.030***
lnPOP	0.031	-1.386*	18.898**	-0.039
FDI	-2.641***	-2.445***	20.651***	-3.435***
INF	-6.438***	-5.184***	44.298***	-3.934***
AGR	-4.064***	-2.245**	17.250**	-2.269*
ΔlnMAN	-11.568***	-10.442***	94.742***	–
ΔEXD	-10.945***	-10.334**	93.415**	–
ΔlnDSER	–	–	–	-6.101***
ΔlnEXCH	–	–	–	–
ΔlnPOP	-2.482***	–	–	-2.557***
ΔFDI	–	–	–	–
ΔINF	–	–	–	–
ΔAGR	–	–	–	-5.360***

Note: Δ is first differenced notation; LLC denotes Levin-Lin-Chu test, IPS is Im-Pesaran-Shin test, and CIPS is Pesaran's (2007) cross-sectional augmented IPS (CIPS) test. Asterisks (***), (**) and (*) denotes statistical significance at 1%, 5% and 10% levels, respectively. The Stata xtcips command is used to compute the CIPS test.

4.4 Cointegration Tests

The Kao residual cointegration test was adopted to assess presence of long-term relation between the variables. The result (Table 5) provides a robust support to reject null hypothesis of no cointegration between the variables at 1% level, thus, portraying that long-term relation exists between them.

Table 5 Result of Kao residual cointegration test

Null hypothesis: no cointegration	*t*-statistic	Probability value
ADF	-8.458	0.000***
Residual Variance	0.013039	
HAC Variance	0.011067	

Note: Asterisk (***) denotes statistical significance at 1% level.

4.5 Estimation Results

The results of panel estimation (Table 6 and Table 7) report short- and long-term estimates of DFE, MG and PMG models, alongside Hausman test results. Also, the cross-sectional short-term estimates for all countries are reported in Table 7. Since the results of Hausman tests portray that the PMG is preferred to MG and DFE estimators, the emphasis is on PMG estimation results.

The results of PMG (column III) portray that external debt has a significant adverse influence on manufacturing sector performance, during the long- and short-term, at 1% level and 5% level, respectively. A percentage increase in total external debt leads to worsening manufacturing sector performance by 0.906% during the long-term and 0.936% during the short-term. The negative relation between external debt and manufacturing sector isn't consistent with Nteegah and Olubiyi (2022) and Osu (2019) finding that external debt promotes manufacturing sector's performance in

Nigeria. Given the enormous size of MINT nations' external debt stock, the outcome portrays that more external debt will worsen manufacturing sector performance either through the debt-overhang effect or the debt crowding-out effect. Moreover, external debt servicing is found to enhance manufacturing sector performance during the long-term at 1% level of significance. An increase in debt servicing by 1% leads to improvement in manufacturing sector's performance by 0.4316% during the long-term. Although external debt stock shows a negative influence on manufacturing output, external debt servicing may impact manufacturing sector positively via increased foreign capital inflow as an expansion in debt servicing portrays a country's capacity to repay both interest and principal on debt obligations.

In addition, exchange rate (depreciation) impacts manufacturing sector's performance negatively during long- and short-term at 1% level. A unit increase in exchange rate lowers manufacturing sector's performance by 0.1159% during the long-term and 0.4549% during the short-term. The outcome supports previous studies in Southern African countries, Nigeria and Sierra Leone (Duramany-Lakkaoh et al., 2021; Falaye et al., 2019; Mlambo, 2020; Nteegah & Olubiyi, 2022; Orji & Ezeanyaeji, 2022), and it suggests that exchange rate depreciation slows down manufacturing sector's performance. The decline in manufacturing output following depreciation is likely on account of inelasticity of the demand for local output by domestic and foreign market (Zhang, 2018).

Moreover, population size impacts manufacturing sector positively during the long- and short-term. Raising population by a percentage lead to manufacturing sector output expansion by 3.739% during the long-term and 13.368% during the short-term, at 1% level and 5% level, respectively. The finding supports Ayyoub et al. (2012) that expansion in population size boosts the performance of Pakistani's manufacturing sector. Rising population size may benefit the manufacturing sector via increasing demand for the sector's output.

More so, FDI has an insignificant positive effect on manufacturing sector's output during the long-term, but the relation is significant during the short-term at 10% level of significance. A percentage increase in FDI raises manufacturing sector's performance by 1.298% in the short-term. The finding supports prior researches in the Middle East and North African (MENA) and Southern African countries including Sierra Leone and Malaysia (Azolibe, 2020; Chandran & Krishnan, 2008; Duramany-Lakkaoh et al., 2021; Mlambo, 2020). The positive influence of FDI on manufacturing sector portrays the role of foreign capital inflow in stimulating the performance of the manufacturing sector in the MINT countries.

Also, inflation rate influences manufacturing sector's output positively during short- and long-term. The outcome implies that raising consumer price level by 1% will raise manufacturing sector's performance by 1.248% and 0.421% during long- and short-term, at 1% level and 5% level, respectively. The outcome substantiates the finding of Falaye et al. (2019) in Nigeria. The supportive role of inflation may be associated with the fact that the corresponding increase in the cost of production is not entirely borne by the producers but captured in the price of output, and thus transferred to the consumer. While the demand for some products is likely to reduce, there is possibility for an increase in the performance of the overall sector, especially when significant outputs of the sector are necessities. Lastly, the error-correction term (ECT) in Table 6 is significant at 5% level, lower than one (1) and signed correctly, revealing that almost 20.83% of disequilibrium during the short-term will be corrected in a year.

Table 6 Panel estimation results of external debt and manufacturing sector relationship

Variables	Dependent Variable: $\Delta lnMAN$

	DFE (I)	MG (II)	PMG (III)
Panel A: Long-run Estimates			
EXD	-0.0082 (0.0021)***	-0.0099 (0.0042)**	-0.0091 (0.0028)***
lnDSER	0.1154 (0.1034)	0.0167 (0.1322)	0.4316(0.1170)***
lnEXCH	-0.0586 (0.0355)*	-0.2948 (0.1253)**	-0.1159 (0.0292)***
lnPOP	2.3496 (0.3371)***	5.1321 (1.664)***	3.7396 (0.4866)***
FDI	0.0469 (0.0444)	0.0356 (0.0429)	0.0281 (0.0426)
INF	0.0045 (0.0025)*	0.0022 (0.0046)	0.0124 (0.0034)***
AGR	-0.0524 (0.0160)***	-0.0165 (0.0164)	0.0324 (0.0265)
ECT	-0.2253 (0.0465)***	-0.5189 (0.1004)***	-0.2083 (0.0863)**
Panel B: Short-run Estimates			
ΔEXD	-0.0085 (0.0009)***	-0.0096 (0.0025)***	-0.0094 (0.0015)**
ΔlnDSER	0.0102 (0.0247)	-0.0179 (0.0600)	0.0249 (0.0409)
ΔlnEXCH	-0.2122 (0.0524)***	-0.5057 (0.1033)***	-0.4549 (0.1217)***
ΔlnPOP	2.0713 (2.9559)	33.459 (17.1129)*	13.3678 (5.8022)**
ΔFDI	0.0082 (0.0102)	0.0149 (0.0099)	0.0129 (0.0072)*
ΔINF	0.0007 (0.0007)	0.0031 (0.0015)**	0.0042 (0.0017)**
ΔAGR	-0.0112 (0.0059)*	-0.0204 (0.0191)	-0.0114 (0.0118)
Constant	-4.3174 (1.4699)***	-43.1769 (24.9845)*	-11.0255 (4.3761)**
Hausman test [Prob.]	7002.19 [0.000]**	12.26 [0.092]	–
Observations	168	168	168
No. of countries	4	4	4
Log likelihood	–	–	215.915

Note: The optimal lag-length is suggested by AIC. DFE = Dynamic Fixed Effect; MG = Mean Group; and PMG = Pooled Mean Group. Values in (.) are standard error and [.] is probability value. Asterisks (***), (**) and (*) denotes statistical significance at 1%, 5% and 10% levels, respectively.

4.6 Results of the Country-specific Short-run Estimates

The results of country-level short-run coefficients (Table 7) reveal external debt stock to impact manufacturing sector's output negatively in all four countries. Compared with the 0.936% negative effect of external debt stock on manufacturing sector in the panel results, the country-level results portray that raising external debt by 1% adversely affects manufacturing sector performance by 0.588%, 0.965%, 0.846%, and 1.311% in Mexico, Indonesia, Nigeria and Turkiye, respectively.

Regarding the other variables, the results portray debt service to significantly and positively influence manufacturing sector's performance in Mexico, but not in the remaining three. Moreover, exchange rate depreciation dampens manufacturing sector's performance in all four nations during the short-term. A unit increase in exchange rate reduces manufacturing sector's output by 0.673%, 0.3473%, 0.163%, and 0.637% in Mexico, Indonesia, Nigeria and Turkiye, respectively. In addition, population size enhances manufacturing sector's performance in all nations except Turkiye. Although FDI fails to impact manufacturing sector's performance significantly in all countries, inflation rate support manufacturing sector during the short-term in all nations except Nigeria. Also, agricultural sector output promotes Indonesia's manufacturing sector during the short-term, hurts Turkiye's manufacturing sector, and insignificant in influencing manufacturing sector output in Mexico and Nigeria.

Table 7 Estimation results of external debt and manufacturing sector relation (country-specific)

Regressors	Dependent Variable: Δ*lnMAN*			
	Mexico	**Indonesia**	**Nigeria**	**Turkiye**
ECT	-0.3396 (0.0803)***	-0.0553 (0.0567)	-0.0633 (0.0275)**	-0.3749 (0.0847)***

ΔEXD	-0.0059 (0.0021)***	-0.0097 (0.0014)***	-0.0085 (0.0018)***	-0.0132 (0.0033)***
$\Delta lnDSER$	0.1396 (0.0355)***	-0.0535 (0.0650)	0.0010 (0.0299)	0.0124 (0.1072)
$\Delta lnEXCH$	-0.6725 (0.1034)***	-0.3473 (0.1219)***	-0.1626 (0.0752)**	-0.6373 (0.1533)***
$\Delta lnPOP$	25.7487 (5.5365)***	9.8187 (1.7435)***	18.9295 (11.5221)*	-1.0258 (3.3304)
ΔFDI	0.0092 (0.0129)	0.0137 (0.0115)	-0.0030 (0.0168)	0.0317 (0.0231)
ΔINF	0.0044 (0.0007)***	0.0084 (0.0021)***	0.0001 (0.0014)	0.0038 (0.0014)***
ΔAGR	-0.0340 (0.0282)	0.0198 (0.0087)**	-0.0068 (0.0070)	-0.0247 (0.0153)*
$Constant$	-18.0353 (3.9059)***	-3.088 (3.1124)	-3.8329 (1.2669)***	-19.1453 (5.1039)***

Note: Values in (.) are standard error. Asterisks (***), (**) and (*) denotes statistical significance at 1%, 5% and 10% levels, respectively.

4.7 Results of Causality Tests

The results of causality tests (Table 8) using the Dumitrescu-Hurlin (2012) heterogeneous panel causality test demonstrate the absence of significant causal relation between external debt and manufacturing sector. The outcome is inconsistent with previous research (Nteegah & Olubiyi, 2022; Osu, 2019), but the outcome supports the finding of Duramany-Lakkaoh et al. (2021). In addition, there is a one-way causality from debt service to manufacturing output, a two-way causal relation between manufacturing output and population (and FDI, and agricultural output), a one-way causality from exchange rate depreciation to manufacturing sector, and from manufacturing sector to inflation rate.

Table 8 Results of Dumitrescu-Hurlin Panel Causality Tests

	lnMAN	EXD	lnDSER	lnEXCH	lnPOP	FDI	INF	AGR
lnMAN	–	0.906	4.227	1.193	3.365***	7.623***	3.284***	4.799***
EXD	1.906	–	0.435	1.802	15.527***	2.849**	2.716**	3.338***
lnDSER	2.184***	0.474	–	1.903	5.025***	9.373***	1.576	1.026
lnEXCH	10.119***	2.869**	2.194	–	5.023***	4.147***	3.909***	3.154***
lnPOP	10.016***	1.504	4.598***	1.219	–	5.316***	2.369*	2.629**
FDI	3.235***	1.374	3.032**	2.901**	1.759	–	1.019	0.327
INF	1.173	1.566	0.483	7.408***	5.391***	5.361***	–	2.767**
AGR	3.469***	1.180	2.496*	1.985	0.867	7.939***	1.054	–

Note: $H_0 : x_{it}$ does not homogeneously cause y_{it}. Asterisks (***), (**) and (*) denotes statistical significance at 1%, 5% and 10% levels, respectively.

4.8 Discussion of Findings

The research's main aim is to evaluate external debt influence on MINT nations' manufacturing sector's performance during the 1980-2021 period, using robust estimation methods like DFE, MG and PMG estimators. The empirical outcomes portray that expansion in external debt stock impact MINT nations' manufacturing sector adversely during short- and long-term. Countries take external loan to provide governments with the opportunity to invest in human and physical capital (infrastructure) to facilitate the growth of sectors of the economy including overall economic activities. However, misallocation or inappropriate utilization of such loans will not only affect the ability to pay back, but also hamper the growth of the sectors of the economy including the manufacturing sector.

Moreover, given the enormous size of the external debt stock of MINT nations, expanding external borrowing may impact the manufacturing sector via reduction in foreign investment in the sector. This can either be on account of debt-overhang effect (a situation in which accumulated debt discourage private investment due to an expected increases in tax to enable the government repay the debt) or debt crowding-out effect (a condition when receipts from exports are used to pay

accumulated debt). In fact, even in a situation where the expansion in debt stock did not lead to an increase in tax, repaying debt obligations would lead to the shift in budgetary allocations away from some (or all) components of public expenditure in favour of interest payments (Abu et al., 2022). Recently, Nigeria's humongous external (and domestic) debt stock has necessitated the government to commit almost all of its annual revenue to debt servicing.

Furthermore, the supportive role external debt servicing on manufacturing sector output contradicts economic theory since debt servicing facilitate the outflow of scare foreign capital, promote balance of payment problem, and deplete external reserves. However, the outcome reflects the possibility of debt servicing acting as an indicator of a country's credit-worthiness and/or capacity to service and repay its debts. This may lead to an increase in foreign direct and portfolio investment in critical sectors of the economy, including manufacturing, thus, enhancing the sector's performance.

The dampening influence of exchange rate (depreciation) on manufacturing sector doesn't align with theory and/or assumption that devaluation of local currency causes domestic outputs relatively cheaper and more competitive in the global market. Exchange rate depreciation is supposed to strengthen the demand for domestic output and raise exports, thus, leading to increases in the performance of the manufacturing sector (Zhang, 2018). Nevertheless, the finding of a negative impact exchange rate (depreciation) suggests the inelasticity of the demand of MINT nations' exports including their imports. This may be connected to the 'not too' impressive performance of countries' industrial sectors. The export of primary products and the huge reliance of manufacturers on imported raw materials and machinery may also be responsible for such relation. In Nigeria, for instance, where more than 90 percent of the export basket is made up of primary products (oil and gas) and the manufacturing (and/or industrial) sector is driven by imports of raw materials and machineries, depreciation hasn't improved the country's exports rather it has increased the import size and the demand for foreign currency, all of which slow down the manufacturing sector performance.

In addition, the positive influence of population size on manufacturing sector's performance may be viewed via two perspectives. First, greater manufacturing performance following increased population size may be associated with increased labour productivity. Second is the higher demand for the sector's output as the population increases.

Furthermore, the positive relation between FDI and manufacturing sector reflects the important role of foreign capital in propelling manufacturing output via technology transfer or adoption, managerial expertise and access to credit, amongst others. Also, the increasing effect of inflation on manufacturing sector's output illustrates that increased consumer price level will stimulate the performance of the manufacturing sector. The positive relation is not unconnected with the fact that manufacturers are able to push increased production costs to consumers via higher prices. Besides, if significant portion of the output are necessities, the increased prices will not reduce the demand. In addition, rising and mild inflation provides an incentive for manufacturing sector's growth.

5 Conclusion

The research's primary object is to access external debt influence on manufacturing sector's performance in MINT nations (Mexico, Indonesia, Nigeria, and Turkiye) from 1980 and 2021, while controlling for external debt servicing, exchange rate, inflation rate, FDI, population size, and agricultural output. Employing the Kao residual cointegration test, the results portray evidence of a long-term relation between the variables. Moreover, results of the Pooled Mean Group, Mean Group and Dynamic Fixed Effects estimators portray a significant dampening impact of external debt stock on manufacturing sector's performance during the short- and long-term. In addition,

debt service promotes manufacturing sector's performance during the short-term, but exchange rate (depreciation) dampens manufacturing sector's performance in all four nations. Also, FDI, population size and inflation rate influence the manufacturing sector positively, but agricultural sector possess no significant influence on the manufacturing sector. Besides, the Dumitrescu-Hurlin heterogeneous panel causality test results portray the absence of causal relation between external debt stock and manufacturing sector. However, there is a one-way causality from external debt service (and exchange rate) to manufacturing output, and a two-way causal relation between manufacturing output and population (and FDI, and agricultural output).

5.1 Policy Recommendations

Consequent on the empirical outcomes, the following recommendations are made. First, governments of the MINT nations are advised to design and implement strategies geared towards revitalising and improving their manufacturing sector. This may include prioritising businesses access to credit facilities, improvement in infrastructures (like roads, electricity, bridges, air and sea ports and rail transportation), and the development of primary sectors or the backward-linkage sectors, such as the agricultural and mining sectors.

Additionally, since it was discovered that external debt stock presents a clear danger for the manufacturing sector performance, the governments are advised to review their fiscal policy stances. In most cases, when mismanagement/misallocation of public funds and unproductive expenditure are non-existent, available resources can sustain public spending. However, if the only option to finance public expenditure is through (external) debt, governments are encouraged to resist the urge and need to commit the loans to current expenditures and unproductive investments. It is recommended that loans be channelled to productive sectors of the economy and components of public expenditure. The spill-over and/or overall effects of such efforts makes repayment very seamless, and therefore, ensures that debt spur growth including promotion of manufacturing sector growth.

Besides, governments (through the monetary authorities) are encouraged to pursue policies which will ensure the stability in exchange and inflation rates, and facilitate the inward foreign capital to their economies, specifically the manufacturing sector. Since it is not possible to recommend efforts to increase the population size despite its positive influence on manufacturing sector, governments are encouraged to investment in human capital development. A small highly-skilled and well-trained population is much more important and relevant than a large unskilled population. While the former will aid the social and economic development of the nation, the later may scuttle economic growth and development as they ensure an increase in the burden on the government. These policies can be complemented with the revision of the tax policy to address the issues of multiple taxations as in the case of Nigeria, and the strengthening the quality of economic institutions in the countries.

Statements and declarations

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

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Availability of data and materials

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