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Adapting to the Digital Revolution: The Transformative Impact of the Fourth Industrial Revolution on Debt Payment

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Abstract

Within the context of the global economy, this research delves into the profound impact of the Fourth Industrial Revolution (4IR) on the dynamics of debt payments. The convergence of Artificial Intelligence (AI), Internet of Things (IoT), and blockchain technology is reshaping how nations approach debt settlements. This study investigates the transformation of international lending and borrowing practices as the 4IR continues to revolutionize trade among developing countries. Employing a comprehensive analysis spanning sixteen years, this paper combines quantitative data on 4IR adoption measures and economic indicators with a qualitative examination of prior research. The investigation explores a significant correlation between the 4IR and foreign debt payments. With the convergence of 4IR technologies, countries can bolster their production competitiveness, stimulate trade volume, and attract foreign investors. Nevertheless, this study also uncovers other aspects related to the 4IR. Rapid technological advancements have exacerbated existing debt inequalities, creating disparities between technologically advanced and less-developed countries.

Keywords: Fourth Industrial Revolution, Debt, Digitalization

JEL Classification: H68, O3, H89

1. Introduction

The Fourth Industrial Revolution (4IR) emerges as the spark for a manufacturing transformation unlike any other in an era marked by technological proficiency and digital innovation. 4IR is the amalgamation of system integration, Internet of Things (IoTs), cloud computing, cyber security, autonomous robots, simulation, and big data and analytics (Vaidya et al., 2018; Pozzi et al., 2023). Industry 4.0 is considered a crucial factor for the inclusive development of countries (UNCTAD, 2021). It also tends to increase the productivity of firms and leads to

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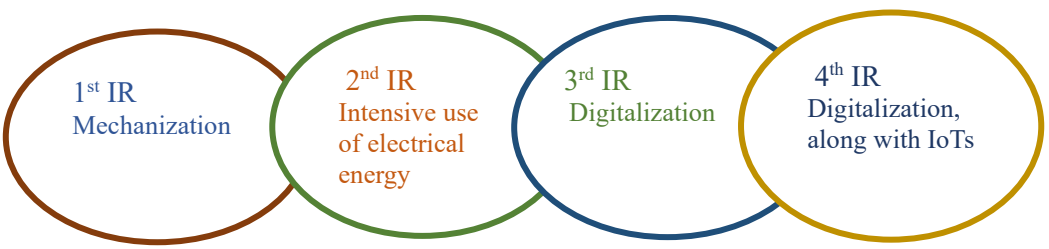
create more jobs (Harintoro, 2023). Rajput and Singh (2019), estimate that 4IR provides opportunities for the upgradation of industries which significantly affects the growth of the countries. The development of 4IR enhances competitiveness, operational efficiency and minimizes waste.

Countries' progress has been linked with structural transformation and technological upgradation, particularly at high value-added sector like industries which in return provides high economic benefits (UNCTAD, 2021). 4IR paves the new way for the industries' resource management and efficient processing (self-production) (Kamble et al., 2018). 4IR is the concept of smart manufacturing, which is derived from a German project, it named as industrial revolution because of the shifts in technologies.

Figure 1. Technological Transformation over time



Source: Authors own work based on literature

The Industrial Revolution started from 1760-1830, it was a transition of production processes. The second industrial revolution was the period of standardization, mass production started from the late 19th century to the early 20th century. IR3 is the time of convergence of analog systems towards digital electronics which starts in the latter half of the 20th century. The early 21st century unfolds the concept of 4IR which is the rapid transformation of internet technologies, big data analytics, and cyber security (Li et al., 2020; Lasi et al., 2014).

With the upgradation of industries' use of technologies like cloud computing, AI has been recognized as one of the efficient tools for addressing debt issues in the countries (Amu et al., 2023). In an era of technological revolution, where the financial system transforms into new dynamics, debt management and applications of debt payments capture global attention. Debt is one of the main macroeconomic indicators that reflects the economic atmosphere of the country, as well as its independence. 4IR attracts foreign investors, reduces risk, efficient

handling of large-scale data, and enhances regulatory compliance (Matvienko and Milkina, 2020). 4IR technologies also worked on the country modernization which firstly increases transparency, secondly, it promotes digital business which tends to increase revenue, thirdly, it simplifies tax procedure and easy accessibility of tax documents, and it also enhances government efficiency, all three indicators reduce the debt burden.

According to IMF 2023, IMF issued to several countries for different development purposes from which Argentina ranked first with $46 billion, Egypt $18 billion, Ukraine $12.2 billion, Ecuador $ 8.2 billion, and Pakistan reserves in 5th position having loan of $ 7.4 billion addition of $ 3billion is accepted in the upcoming ninth month. The debt situations of South Asia, the Middle East, and Central Asia. Asia is mostly categorized as transition economies which began to emerge in the 1990s, converting command economies into market-based economies. These nations implemented sociocultural, political, and economic reforms while frequently incurring debt to do so. Some nations have significant debt levels, and instead of investing in their economies, foreign debt finance is used to acquire consumer items (Sagdic et al., 2020). Economies move because of low domestic saving and low capital accumulation, budget deficit along with other macroeconomic factors. Maldives takes loans because of external vulnerabilities and low reserves. Pakistan is one of the top listed debtors of the IMF, it takes loans for debt repayments.

4IR refers to high-tech exports which hold a crucial role in debt repayments of developing and developed nations. It includes high-value-added products that generate revenues and contribute to achieving trade surplus, it also intends to reduce tax burden and plays an important role in financial economic stability (Malik and Siddiqui, 2001). A nation's ability to honor its debt obligations can be improved by diversifying its income sources, minimizing reliance on one industry, and protecting the country from economic shocks.

With an emphasis on developing countries, this study seeks to clarify the complex connections between 4IR technologies and debt management. Evaluating the impact of 4IR technology adoption on a nation's debt repayment policies and overall economic stability is the main goal of the research. According to the theory, nations who use 4IR have improved financial resilience, drawn in foreign capital, reduced risks, and improved the way they handle massive amounts of financial data. In addition, it is expected that the modernization brought about by 4IR technologies such as, artificial intelligence and cloud computing would boost government revenue collection, efficiency, and transparency, which will eventually lessen the

load of the national debt. The study will employ the Panel Corrected Standard Errors (PCSE) method. The study analyzes the data issues by exploring the debt situations of countries like Armenia, Cambodia, China, Georgia, India, Indonesia, Lao PDR, Mongolia, Nepal, Pakistan, Sri Lanka, Thailand, Türkiye and Vietnam. The goal of the study is to offer insightful information on the precise processes that 4IR uses to support or undermine debt repayment plans in various economic situations. Impact of 4IR on debt repayment is significant, providing policymakers, economists, and academics with a basis for well-informed decision-making and strategic planning in an era characterized by technological advancement and the digital revolution. Trade openness and income creation, which eventually lessens the weight of the national debt.

For further understanding, this article is divided into different sections like literature review, theoretical framework, data and methodology, results and discussion and then conclusion and policy recommendations.

2. Literature Review

Industry 4.0 is one of the most discussed topics by policymakers. The concept of 4IR is defined in a different dimension along with different macroeconomic indicators. According to Lasi et al. (2014), 4IR can be elaborated in two different development terms. Firstly, it triggers the operational framework, secondly, it changes the social and economic behavior of a country. Similarly, another study describes 4IR in terms of smart factories, which means automation in the manufacturing process. Utilization of smart technology in industries can enhance productivity and lead to generating more revenue (Lucke et al., 2008).

Innovative methodologies in 4IR enhance the work capacity. The technology records the manufacturing steps and automates that process, so it may be completed within a short time duration (Loskyll, 2013; Brandherm and Kroner, 2011). Lee et al. (2020), Wang et al. (2020), and Gan et al. (2020) explored the concept of 4IR in terms of machine learning. The paper explored that 4IR works under the concepts of artificial intelligence (AI), the statistical algorithm of machine learning, and model optimization. It increases the industry's efficiency as compared to the traditional methods of production.

A similar study was carried out by Fatorachian and Kazemi (2018) to provide deep insight into Industry 4.0 by reviewing the previous literature on 4IR. The study used a deductive research approach in the case of China. It incorporates variables such as software systems, IoTs, cyber security systems, and the Internet. The study came out with the results that promote smart manufacturing.

Numerous studies attempt to analyze the impact of Industry 4.0 on different macroeconomic indicators such as a study attempts to analyze the influence of Industry 4.0 on the reductions of debt obligations through finding evidence from BRICS countries over the year 2019. A multiple regression model was employed to test the hypothesis. The results find that the significance of developed countries is more than that of developed countries. The authors highlight that the debt burden of the selected sample was reduced by up to 45% (Matvienko and Milkina, 2020). Many other authors carried out on the same topic which tends to result from the significant impact of Industry 4.0 on debt payments along with the different dynamics of digitalization (Sergi, 2003; Sergi et al., 2019; Ragulina et al., 2019 and Shulus et al., 2020).

The majority of OECD and Commonwealth nations have avoided implementing fully AI-powered and ICT systems for their financial sectors, creating a potential debt crisis. The study, which is grounded in Creswell's mixed-method research methodology and Marilyn's ex-post facto research design, examines the connection between the debt management dilemma and the role of ICT in 21st-century polities (Amu et al., 2023).

A country's economic stability can be analyzed through its macroeconomic indicators, a study attempts to find the relationship between human capital and industry 4.0 on unemployment. The fixed effect, random effect, and generalized method of the moment were used to determine results over 46 Asian countries. Results confirmed that increases in high technology increase unemployment (Tran et al., 2023). Li et al. (2020) attempts to analyze the impact of machine learning and credit rating in the era of Industry 4.0. The analysis consists of GCC countries over the eight years. Different machine-learning approaches are used to test hypotheses. The results show a significant relation among variables.

Sagdic et al. (2020) explores the factors affecting external debts in Central Asia and the Caucasus economies from 1995-2017 using panel data analysis. The findings indicate that while inflation, the current account deficit, and domestic savings have a negative impact on external debt, public spending, and debt servicing have a favorable impact. Khachaturyan and Ponomareva (2018), by using STEP-analysis to examine "Industry 4.0" developments made by Russian high-tech firms. It emphasizes the significance of developing technological bases, utilizing AI, exploring alternative energy sources, accelerating biotechnology, and the number of R&D organizations in the aerospace and military-industrial complex.

Similarly, Aladejare (2023) looked at the effects of external debt on life expectancy in emerging West African nations between 1981 and 2020. It was

discovered that macroeconomic volatility and unmanageable external debt reduce longevity over the long run, indicating that poor external debt management encourages poverty in these countries. In sum, numerous literatures have been done on Industry 4.0 but few are concerned with the relationship between 4IR and debt payments.

The impact of the 4IR on debt repayment in developing nations is examined in the case of developing nations with strong empirical evidence. The present study looks at actual cases and gives readers a thorough grasp of the multidisciplinary method, which combines policy studies, technology, and economic analysis. In the digital age, research provides decision-makers with useful information.

3. Theoretical framework

The study uses technological determinism to examine the impact of the 4IR on debt payment, focusing on how 4IR technologies like IoT, cloud computing, and artificial intelligence shape economic structures and debt management strategies. Structural Transformation Theory investigates the evolution of the economic structure after 4IR. It focuses on the effects of 4IR technologies on industries, production processes, resource management, and debt dynamics, demonstrating the connection between debt repayment strategies and technological breakthroughs (Khachaturyan, 2013).

This study also incorporates the Solow models for empirical estimations. It discusses the role of technology in labor productivity and economic growth, with renowned theories like Solow's growth model and Romer's aggregate production model (Kendrick, 1956; Solow, 1957). The authors examine real-world examples of countries adapting to the digital revolution, focusing on foreign investments, financial processes, and debt repayment strategies. Their interdisciplinary approach offers a holistic understanding of the multifaceted implications of 4IR on national economies Romer (1990). The book by Mazur (2022), also discusses the impact of 4IR on various aspects of society and the economy especially on the labor market.

Romer (1990) and Solow (1957) suggest technological change leads to increased output and capital accumulation. The Cobb-Douglas production function is used to estimate FinTech's impact on economic growth. Solow's (1957) neoclassical growth model incorporates technology as an exogenous variable, dividing input factors into land, labor, capital, and growth, with a simple growth function for estimation.

$$Y = F(K, L * E) \quad (1)$$

Where Y is the output, K defines capital, L is the number of workers in the labor market, and E indicates efficiency. $L * E$ represents the workers and technological progress. In order to highlight how technology advancement fosters economic growth through new methods, devices, and processes, the endogenous growth hypothesis was developed (Hess and Lawata, 1997). Romer (1990) introduces the endogenous growth model. Rather than material capital, human capital is the primary focus. The study said that without human capital, technology could not be developed. Since technology is regarded as a non-rival good and has a fixed cost, the following is the model under endogenous growth theory:

$$\dot{A} = \delta H_A A \quad (2)$$

$\dot{A}$ represents the knowledge required to access fully available technology in addition to the input of human capital, H. The interpretation of human capital in equation (3) below results in the creation of novel production concepts. Thus, the following is the new output function.

$$Y = (H_Y A)^{\alpha} (LA)^{\beta} (K)^{1-\alpha-\beta} \quad (3)$$

The above terms mentioned in equation 3, abbreviated as Y represents the output were, H_Y is the human capital used to produce the output, and K and L represent capital and labor as a factor of production. This endogenous growth model is used for efficient production but needs to employ human capital fully.

4. Data and Methodology

4.1. Data and Variables

The present study attempts to examine the impact of Industry 4.0 on foreign debt payments. The dataset of Hi-Tech exports (4IR) provides a comprehensive view of the economic environment, which is extracted from world development indicators. The dataset was measured yearly from 2001-2020. Debt stock as % of GDP is considered the main explanatory variable by following the methodology of Tran et al. (2023). The data of variables of interest that is unemployment, inflation, trade deficit, and research and development expenditure is taken from WDI over the same span as for 4IR. The GDP per capita for selected Asian countries was also taken from WDI for the same time. The used dataset was thoroughly cleaned by addressing the missing values and looking out whether the data was uniform. To test out the hypothesis, statistical methodology of GMM is used.

Table 1. Variables and Sources of Variables

Abbreviations	Indicator name	Proxy	Sources
EXDR	External debt ratio	Ratio to GDP	WDI
4IR	Hi-Tech Export	Ratio to GDP	WDI
UE	Unemployment	% of GDP	WDI
INF	Inflation	Consumer price %	WDI
TO	Trade Deficit	Ratio to GDP	WDI
FDI	Foreign Direct Investment	Ratio to GDP	WDI

4.2. Methodology

To test the hypothesis of whether there is an impact of 4IR on foreign debt payments. We implied a generalized method of moment panel data model over the selected time of sixteen years 2007-2022.To check the statement's validity, we start with the general equation (4).

$$EXDR_{it} = \beta_0 + \beta_1 4IR_{it} + \beta_2 UE_{it} + \beta_3 INF_{it} + \beta_4 TO_{it} + \beta_5 FDI_{it} + \varepsilon_{it} \quad (4)$$

Where $i = 1, 2, \dots, N$; $t = 1, 2, \dots, T$ (N is total number of Asian countries, t is the time of observation), and identically distributed error terms ε_{it}. This study accomplishes the objective by following the methodology of Ikpesu et al., (2022). This study uses the GMM technique to achieve its goal. Balance panel data model, 14 countries were used in the estimation process. Pre and post-testing of panel data models were also employed.

Where, to estimate the hypothesis following cluster of variables is used. EXDR represents External debt stocks in % of GDP (Cahyadin and Ratwianingish, 2020; Tran et al., 2023) it is the common measure that reflects the country's economic condition. Hi-Technology is taken as the proxy of the 4IR, followed by (Sozinova, 2018; Tran et al., 2023). UE represents the unemployment rate % of the labor force which is in line with (Sahnoun and Abdennadher, 2019; Gaponenko and Glenn 2020; Raifu, 2021). TD represents trade deficit followed by (Ogbeide et al., 2015; Kirema, 2019). INF abbreviated as inflation measure as consumer price percentage (Ogbeide et al., 2015; Kirema, 2019). FDI shows foreign direct investment in % of GDP followed by Ogbeide et al. (2015).

A strategy framework directs the creation of variables and the choice of panel countries for this research. An important metric for determining a country's level of debt in relation to its economic production is the External Debt Ratio (EXDR), which is the dependent variable. Based on factors that guarantee geographic diversity, economic size, and relevance to (4IR), Armenia, Cambodia, China, Georgia, India, Indonesia, Lao PDR, Mongolia, Nepal, Pakistan, Sri Lanka, Thailand, Türkiye, and Vietnam are included in the panel. These nations' diverse

geographic locations, economic sizes, and developmental stages make it possible to conduct a thorough investigation of how 4IR affects debt repayment.

The selection of independent variables, namely trade deficit, foreign direct investment, inflation, unemployment, and high-tech exports, aims to encompass a range of economic aspects. The countries' participation in 4IR, the availability of data, and the implications for policy are among the selection factors. This paradigm seeks to contribute to a more comprehensive understanding of the transformative impact of technological improvements on debt dynamics by offering insights into the complex linkages between 4IR related variables and EXDR across a range of economies.

5. Results and discussions

This paper follows the methodology of Henningsen and Henningsen (2019). To deal with missing values and ensure data integrity and reliability, data cleaning methods were initially put into place. Following standard practices and taking the data's nature into account, missing values were either imputed or removed. The dataset was test-trained with a 70% training and 30% testing split ratio, enabling a successful assessment of the performance of the linear regression model.

Many assumptions underlying linear regression were carefully evaluated after the data processing using the PCSE technique. These included determining probable outliers, testing for residual normality, looking for homogeneity of variance, and examining multicollinearity among predictor variables. After verifying the accuracy and reliability of the data. A descriptive analysis of our study is as follows:

Table 2. Descriptive Statistics

Variables	Observations	Mean	St. Dev	Min	Max
EXDR	224	53.06	43.53	8.41	243.56
4IR	224	2.63	5.40	.003	29.293
TD	224	-7.48	10.70	-46.87	13.56
INF	224	6.60	7.15	-1.40	72.31
UE	224	6.10	4.70	.14	20.71
FDI	224	-3.79	6.13	-43.003	37.30

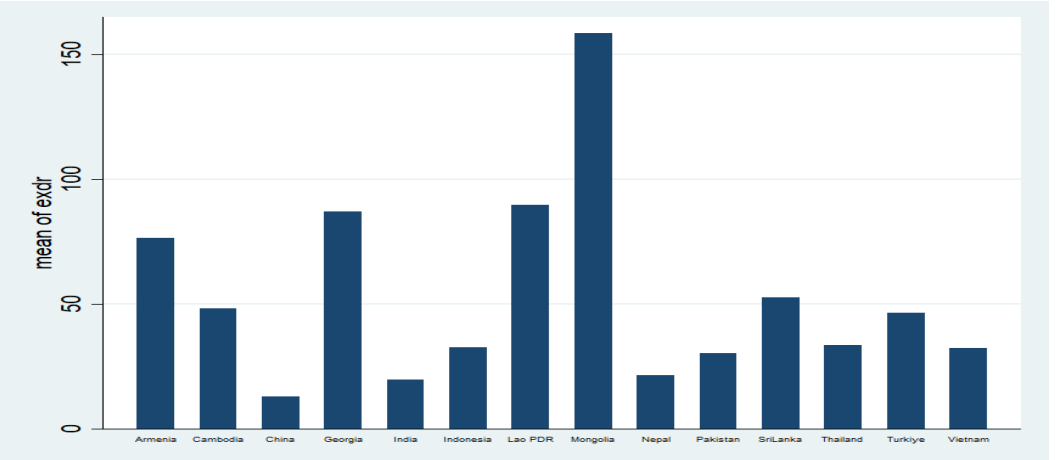
Source: World Development Indicators

Table 2 presents summary statistics for the selected variables. The variables are taken from world development indicator (WDI) of selected variables such as EXDR, 4IR, TD, INF, UE, and FDI for the selected Asian countries such as Armenia, China, Georgia, Indonesia, India, Cambodia, Lao PDR, Sri Lanka, Mongolia, Nepal, Pakistan, Thailand, Türkiye and Vietnam respectively. Sample collected on behalf of data availability. Two hundred and twenty-four observations were present in the dataset over the time of sixteen years from 2007-2022.

This study incorporates graphical analysis before the empirical analysis to set the landscape of external debt stock as the percentage of GDP and the ratio of Hi-Tech exports which is taken as the proxy of 4IR. For a country's economic profile, the relationship between external debt and high-tech exports is essential. A strong high-tech export sector can produce income and boost economic stability, whereas high external debt might strain budgets and impede research. Policymakers and economists must comprehend this dynamic to comprehend a country's fiscal health and place in the global economy.

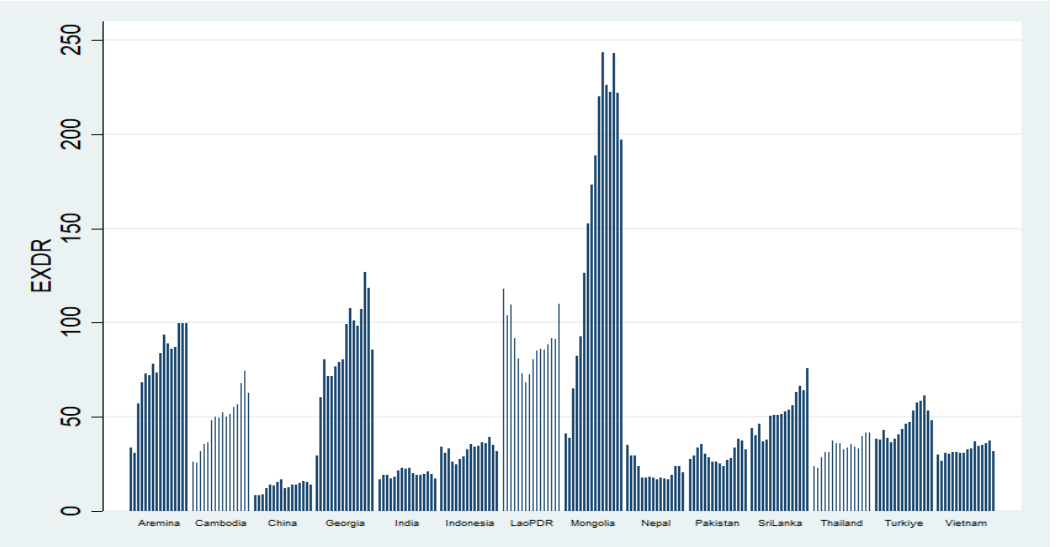
Figure 2 represents the selected sample outlook of external debt stock % of GDP. Mongolia, Lao PDR, and Armenia ranked at the top of the list. The total debt of Mongolia is $33.8 bn due to some economic vulnerabilities, currency depreciation, inefficient loan consumption, and limited diversification. Armenia, Cambodia, and Lao PDR almost lie on the same level. These countries take loans for their development purposes like large-scale projects, hydropower projects, etc. The debt ratio in South Asian countries was also high, Sri Lanka's debt ratio surpassed its GDP by 118 percent. Pakistan also debt rate is also high which is over three-quarters of its GDP. Turkey's external debt ratio is about 51.3% of its GDP.

Figure 2. External debt stock as per the ratio of GDP over the selected countries



Source: Authors work based on the dataset of WDI 2023

Figure 3. The external debt as a ratio of GDP over time in selected Asian countries



Source: Authors own work based on the dataset of WDI 2023

Figure 3 shows the external debt as a % of GDP over time in selected Asian countries from 2007-2022. The graph indicates that there will be a reduction in the debt burden in 2022 in some countries like Indonesia and Turkey. In most of the country's debt burden increases over time. Rapid economic expansion, expenditures in infrastructure, and low interest rates were all blamed for the increase in external debt as a percentage of GDP in Asian economies (Faraglia et al., 2010). While budget deficits fund social programs and subsidies, governments rely on external borrowing to fund these initiatives. For these rapidly evolving economies, striking a sustainable balance between borrowing and debt remains a major concern.

External debt cannot be always taken in a negative term, but it leads to maintaining the economic stability of a country's efficient management of debt sources increasing productivity and efficiency of the economy. But on the darker, it could be harmful in case of excessive borrowings from national and international financial institutions. Several studies explore that investment in highly equipped industries can reduce the debt burden of the economies (Sozinova, 2018; Tran et al., 2023).

Figure 4. Hi-Tech exports in Selected Asian Countries over the Time

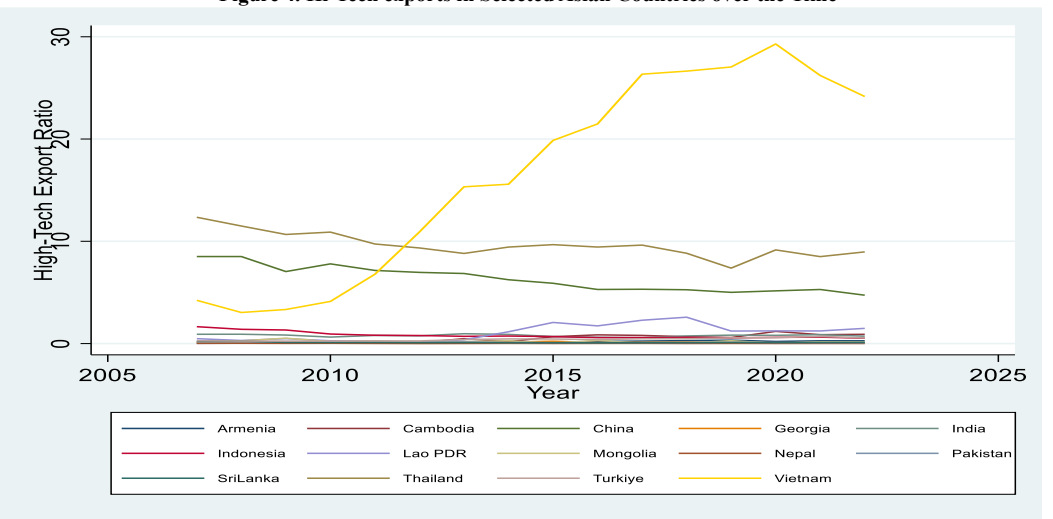
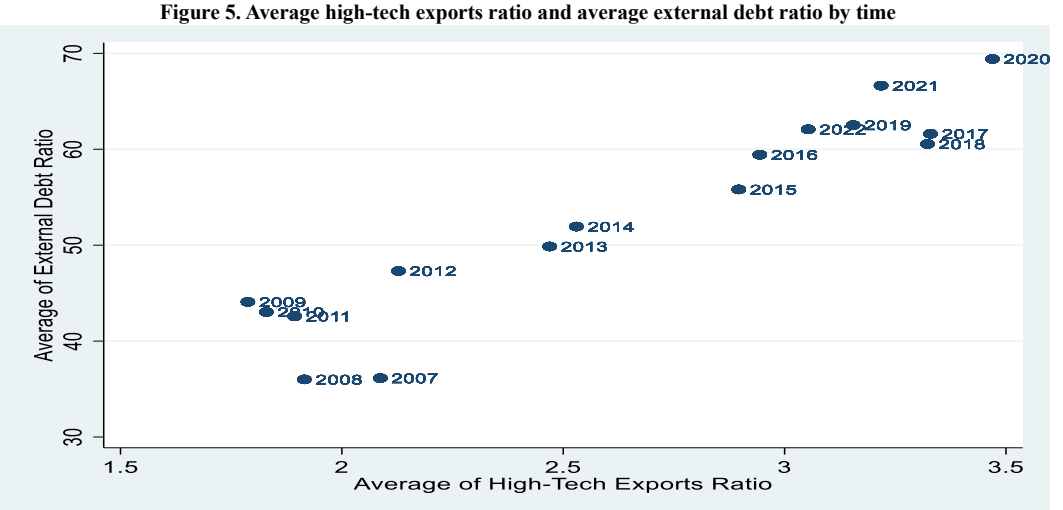


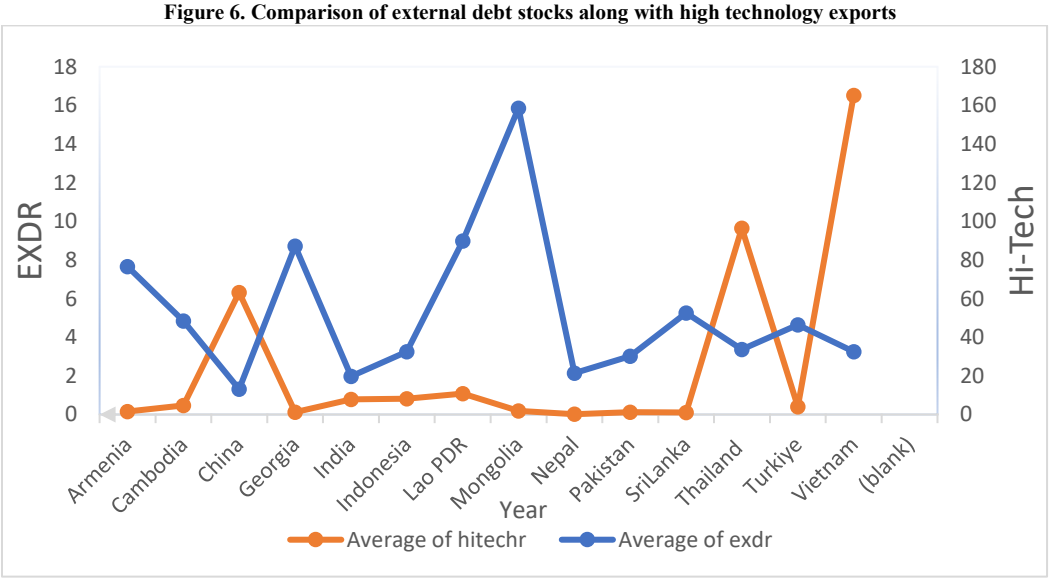
Figure 4 shows the trend of hi-technology exports over time from the selected sample of countries. China has a higher rate of exports all over the world by beating the US it becomes the largest exporter. Vietnam, Indonesia, and Lao PDR also reserve their place as hi-tech exporters in Asian countries. Exporting high-tech goods demonstrates a nation's capacity for cutting-edge research and development, which supports trade balance, economic growth, and job creation. China, a major exporter of goods requiring advanced technology, has a significant impact on the world economy.

Figure 5. Average high-tech exports ratio and average external debt ratio by time



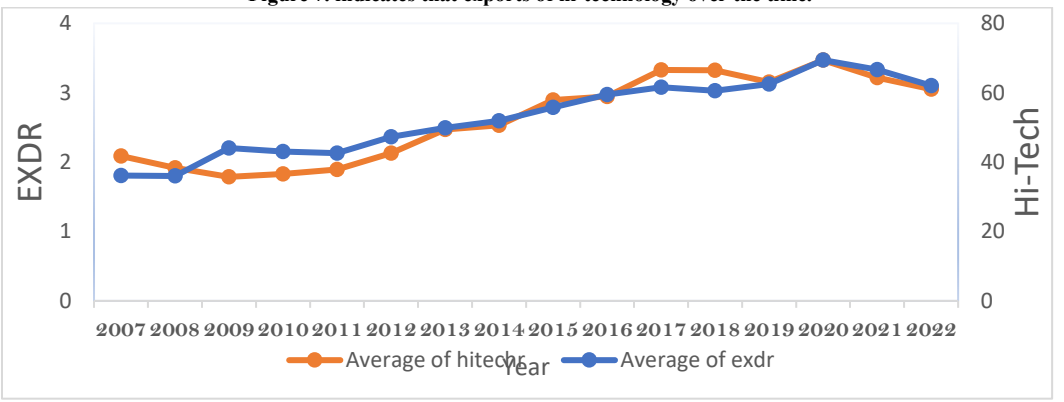
The given scatter plot given in Figure 5 illustrates the relationship between the average high-tech exports to GDP ratio and the external debt to GDP ratio for various years. At first glance, there doesn't seem to be a pronounced linear correlation between the two variables as the data points are somewhat dispersed. However, on closer inspection, one can discern a positive association, suggesting that as the average high-tech export ratio increases, there tends to be an increase in the external debt to GDP ratio as well. This relationship is particularly evident in recent years. For instance, years such as 2021, 2020, and 2019 are situated on the right side of the graph, indicating a higher average of high-tech exports ratio. Their external debt ratios also reflect a general upward trend, with variations between the years. Conversely, earlier years like 2008 and 2007, which are placed on the left side of the graph, show a lower high-tech exports ratio, and are associated with a comparatively lower external debt to GDP ratio. The middle years, like 2012 and 2015, fall somewhere in between, exhibiting moderate levels of both metrics. Overall, while the scatter plot does not show a strict linear relationship, there's an observable positive association between high-tech exports and external debt over the years, suggesting that as one increases, the other tends to follow suit.

Figure 6. Comparison of external debt stocks along with high technology exports



Source: Authors own work based on the dataset of WDI-2023

Figure 7. indicates that exports of hi-technology over the time.



Source: Authors own work based on the dataset of WDI-2023

Asian economies are rapidly advancing in terms of industrialization, technical advancement, and international integration, making them a major factor in the world economy. Additionally, Asia generates 75% of the world's robotics, 50% of the world's high-tech exports, and more than 50% of the world's autos. Figures 6 and 7 reflect the condition of Asian countries over time that external debt and hi-technology exports move inversely to each other's that debt burden is reduced with the increase in industrialization. To empirically test our hypothesis, current study follows the technique of (Ikpesu et al., 2019; Shetewy et al., 2022).

To understand the influence of the 4IR on external debt payments, this study employs a linear regression technique, specifically the Panel Corrected Standard Errors (PCSE) method. The regression results are as follows:

Table 3. Results for the determinants of external debt

Variables	Coefficients	Z-Value
Hi-Tech exports	-1.86***	(-7.76)
Unemployment	1.73***	(3.66)
Trade Deficit	0.88**	(2.42)
Foreign Direct Investment	-2.54**	(-2.10)
Inflation	-0.31	(-0.96)
Constant	46.36***	(7.94)
Number of Observations	224	
Number of Countries	14	
Wald Chi2(5)	179.51	
P-Value	0.0000	

Note: *** *p<.01*, ** *p<.05*, * *p<.1*

The results indicate that a one percentage unit increase in hi-technology exports results in a decrease of 1.832 percentage units in the debt burden as a percentage of GDP. This inverse relationship is consistent with findings from Sozinova (2018) and Tran et al., (2023). The underlying rationale is that governments investing in high-tech research potentially become more innovative,

thereby reducing their reliance on external borrowing as they augment their resources and revenue streams.

An increase in unemployment by one unit leads to a 1.7303 percentage unit rise in the external debt burden as a percentage of GDP. This positive correlation aligns with the Keynesian economic theory, suggesting that governments might resort to deficit spending and accumulate debt to stimulate economic activity and reduce unemployment during periods of high unemployment. This observation is supported by studies from Sahnoun and Abdennadher (2019), Gaponenko and Glenn (2020), and Raifu (2021).

The results expose a positive coefficient of around 0.8767 for trade, suggesting that a one percentage point upswing in the trade deficit to GDP ratio results in a corresponding 0.8767 percentage unit upturn in the external debt as a percentage of GDP. This statistically significant correlation, evidenced by a p-value of 0.015, aligns with the conclusions drawn by Ogbeide et al. (2015) and Kirema (2019).

The inflation rate exhibits a negative but statistically insignificant coefficient, suggesting that higher inflation is associated with lower external debt. This can be explained by the Fisher effect, which theorizes that escalating inflation leads to increased nominal interest rates, making debt servicing more costly and discouraging borrowing. This relationship is further elaborated upon by Ogbeide et al. (2015) and Kirema (2019).

The examination reveals a statistically significant negative coefficient associated with FDI, implying that increased FDI levels are correlated with reduced external debt. This substantiates the idea that FDI has the potential to inject capital and technology into an economy, alleviating the necessity for external borrowing to fund developmental projects. This perspective is reinforced by Ogbeide et al. (2015).

Concluding the analysis, the regression study sheds light on noteworthy connections between diverse economic indicators and the external debt burden as a percentage of GDP. This investigation underscores the pivotal roles played by factors including the unemployment rate, hi-tech research, trade deficit, and foreign direct investment in shaping the external debt profile of a country. These findings underscore the intricate interplay between economic variables and their impact on a nation's external debt dynamics. Numerous research avenues exist for assessing the impact of the 4IR. One intriguing avenue involves investigating whether the

influence of 4IR on debt-related issues is consistent across developed and developing countries.

5. Conclusion and Policy Recommendations

In the context of the global economy, this research delves into the profound impact of the 4IR on the dynamics of debt payments. The convergence of Artificial Intelligence (AI), Internet of Things (IoT), and blockchain technology is reshaping how nations approach debt settlements. This research investigates the transformation of international lending and borrowing practices as the 4IR continues to revolutionize trade among developing countries. Using a comprehensive analysis spanning over sixteen years, this paper uses the PCSE linear regression approach. According to the regression study, there is a positive association between the unemployment rate and foreign debt, indicating that governments may borrow from abroad to promote economic growth. Conversely, there is a negative association between high-technology research investments, this suggests that technological progress could lessen the need for external borrowing. While foreign direct investment can help to offset this, trade still entails borrowing from outside with the convergence of 4IR technologies, countries can bolster their production competitiveness, stimulate trade volume, and attract foreign investors.

In light of the research findings, policymakers are urged to adopt a multifaceted approach to navigate the impact of the 4IR on debt dynamics. First, prioritize investments in technology education to cultivate a skilled workforce capable of reducing reliance on external borrowing for technological advancements. Second, incentivize domestic high-technology research to diminish the need for external borrowing, aligning with the negative association found in the study. Third, diversify sources of FDI to balance technological deficits, and implement policies fostering a strategic approach to attract diverse investments. Embrace 4IR technologies to enhance production competitiveness, streamline trade processes, and stimulate trade volume, thus reducing the necessity for external borrowing. Lastly, formulate robust debt management strategies considering the positive association between unemployment rates and foreign debt, ensuring a balanced approach to promote economic growth without incurring unsustainable financial burdens. Engage in global collaborations to establish standardized frameworks for emerging technologies, facilitating smoother cross-border transactions, and creating a conducive environment for global trade.

References

Aladejare, S. A. (2023). Does external debt promote human longevity in developing countries? Evidence from West African countries. Fudan Journal of the Humanities and Social Sciences, 16(2), 213-237.

Amu, C. U., Nwezeaku, N. C., Akujuobi, L. E., Ozurunba, B. A., Njie, S. N., Wogu, I. A. P., & Misra, S. (2023). The politics of public debt management among rising hegemonies and the role of ICT: Implications for theory and practice for 21st century polities. *International Journal of Electronic Government Research,* 15(3), 1-12.

Brandherm, B., & Kröner, A., (2011). Digital product memories and product life cycle. *Proceedings of the 7th International Conference on Intelligent Environments*, Nottingham, 374–377.

Cahyadin, M., & Ratwianingsih, L. (2020). External debt, exchange rate, and unemployment in selected ASEAN countries. *Jurnal Ekonomi & Studi Pembangunan,* 21(1), 16-36.

Faraglia, E., Marcet, A., & Scott, A. (2010). In search of a theory of debt management. *Journal of Monetary Economics*, 57(7), 821-836.

Fatorachian, H., & Kazemi, H. (2018*).* A critical investigation of Industry 4.0 in manufacturing: Theoretical Operationalisation framework. *Production Planning & Control,* 29(8), 633-644.

Gan, L., Wang, H., & Yang, Z. (2020). Machine learning solutions to challenges in finance: An application to the pricing of financial products. *Technol. Forecast. Soc. Change*. *Technological Forecasting and Social Change*, 153. Available At: https://doi.org/10.1016/j.techfore.2020.119928

Gaponenko, N.V., & Glenn, J.C. (2020). Technology industry 4.0: Problems of labor, employment, and unemployment. *Studies on Russian Economic Development,* 31(3), 271-276.

Harintoro, G. J., Widyantoro, G. B. H., Aaron, A., Muhamad, F., Gaol, F. L., Matsuo, T., & Filimonova, N. (2022). The impact of the industrial revolution 4.0 on small medium enterprises (SME) agribusiness in the electronic payment sector. *Proceeding of Fifth ICCNCT*, Springer Nature Singapore, 445-459.

Henningsen, A., & Henningsen, G. (2019). *Chapter 12 - Analysis of panel data using R.* in Tsionas, M. (2019). *Panel Data Econometrics*, Academic Press,

345-396. Available At: https://doi.org/10.1016/B978-0-12-814367-4.00012-5 .

Hess, G.D., & Iwata, S. (1997). Asymmetric persistence in GDP? A deeper look at depth. *Journal of Monetary Economics*, 40(3), 535-554.

Ikpesu, F., Vincent, O., & Dakare, O. (2019). Growth effect of trade and investment in Sub-Saharan Africa countries: Empirical insight from Panel Corrected Standard Error (PCSE) technique. *Cogent Economics & Finance*, 7(1), 1-13.

Kamble, S.S., Gunasekaran, A., & Gawankar, S.A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection,* 117, 408-425.

Kendrick, J.W. (1956). Productivity trends: Capital and labor. *The Review of Economics and Statistics*, 38(3), 248-271.

Khachaturyan, A., & Ponomareva, S. (2018). *Scientific and technical development of Russia's high-tech companies in the context of introducing the concept of "Industry 4.0" and the digital economy development*. *SHS Web of Conferences*, 55, 1-6.

Khachaturyan, A.G. (2013). *Theory of Structural Transformations in Solids*. Courier Corporation.

Kirema, P.K. (2019). Effect of Trade openness on unemployment rate in Kenya. Doctoral Dissertation, University of Nairobi.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering,* 6, 239-242.

Lee, H., Kim, S.G., Park, H., & Kang, P. (2014). Pre-launch new product demand forecasting using the Bass model: A statistical and machine learning-based approach. *Technological Forecasting and Social Change*, 86, 49-64.

Li, J. P., Mirza, N., Rahat, B., & Xiong, D. (2020). Machine learning and credit ratings prediction in the age of the fourth industrial revolution. *Technological Forecasting and Social Change*, 161,1-20. Available At: https://doi.org/10.1016/j.techfore.2020.120309.

Lucke, D., Constantinescu, C., Westkämper, E. (2008). Smart factory - A step towards the next generation of manufacturing. In: Mitsuishi, M., Ueda, K., Kimura, F. (eds) Manufacturing Systems and Technologies for the New

Frontier. Springer, London. Available At: https://doi.org/10.1007/978-1-84800-267-8_23

Malik A, & Siddiqui R. (2001). Debt and economic growth in South Asia. *The Pakistan Development Review*, 40(4), 677-688.

Mazur, S. (2022). *Industrial Revolution 4.0: Economic Foundations and Practical Implications* (First Edition). Routledge.

Ogbeide, F. I., Kanwanye, H., & Kadiri, S. (2015). The determinants of unemployment and the question of inclusive growth in Nigeria: Do resource dependence, government expenditure and financial development matter*? Montenegrin Journal of Economics,* 11(2), 49-65.

Pozzi, R., Rossi, T., & Secchi, R. (2023). Industry 4.0 technologies: Critical success factors for implementation and improvements in manufacturing companies. *Production Planning & Control*, 34(2), 139-158.

Ragulina, Y.V. (2019). *Priorities of development of industry 4.0 in modern economic systems with different progress in formation of knowledge economy.* In: Popkova, E., Ragulina, Y., Bogoviz, A. (eds.) Industry 4.0: Industrial Revolution of the 21st Century. Studies in Systems, Decision and Control, 169, 167–174.

Raifu, I.A. (2021). The role of institutional quality in oil price-unemployment nexus in African and Asian oil-exporting countries. Available At: https://doi.org/10.21203/rs.3.rs-953547/v1

Rajput, S., & Singh, S.P. (2019). Connecting circular economy and industry 4.0. *International Journal of Information Management*, 49, 98-113.

Romer, P. M. (1990). The problem of development: A conference of the institute for the study of free enterprise systems. *Journal of Political Economy*, 98(5), 71-102.

Sagdic, E. N., Yildiz, F., & Sayin, H. H. (2020). Doğrudan Yabanci Yatirimlar, Vergi Gelirleri Ve Ekonomik Büyüme İlişkisi: Kirilgan Beşli Ülkeler Örneği. Süleyman Demirel Üniversitesi Vizyoner Dergisi, 11(28), 680-699.

Sahnoun, M., & Abdennadher, C. (2019). The nexus between unemployment rate and shadow economy: A comparative analysis of developed and developing countries using a simultaneous-equation model. *Kiel Institute for the World Economy Economics Discussion Papers,*2019-30*,* 1-28.

Sergi, B.S., (2003). *Economic Dynamics in Transitional Economies: The Four-P Governments, the EU Enlargement, and the Bruxelles Consensus.* Routledge, New York.

Sergi, B.S., Popkova, E.G., Vovchenko, N., Ponomareva, M., (2019). Central Asia and China: Financial development through cooperation with Russia. *International Symposia in Economic Theory and Econometrics, Asia-Pacific Contemporary Finance and Development*, 26, 141-164.

Shetewy, N., Shahin, A.I., Omri, A., & Dai, K. (2022). Impact of financial development and internet use on export growth: New evidence from machine learning models. *Research in International Business and Finance*, 61, 1-20.

Shulus, A.A., Akopova, E.S., Przhedetskaya, N.V., & Borzenko, K.V. (2020). Intellectual production and consumption: A new reality of the 21st century. *Lecture Notes in Networks and Systems*, 92, 353-359.

Solow, R.M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3), 312-320.

Tran, O., Le, T.D., & Hang, N.P.T. (2023). Impacts of human capital, the fourth industrial revolution, and institutional quality on unemployment: An empirical study at Asian countries. *Journal of Eastern European and Central Asian Research*, 10(2), 238-250.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing*, 20, 233-238.

Wang, X., Zeng, D., Dai, H., & Zhu, Y. (2020). Making the right business decision: forecasting the binary NPD strategy in Chinese automotive industry with machine learning methods. *Technological Forecasting and Social Change,*155. Available At: https://doi.org/10.1016/j.techfore.2020.120032