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GVCs and environmental sustainability in MENA: Do digitalization and institutions make a difference?

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Abstract

Currently, the advent of digitalization has profoundly altered the structure of Global Value Chains (GVCs), with implications for environmental sustainability (ENS). Notwithstanding its importance, the dynamics of participation in GVCs, ENS, and digitalization have not been thoroughly investigated in empirical literature. On the other hand, despite its rapid evolution and growing popularity, GVCs participation is rarely considered when analyzing factors influencing ENS in the Middle East and North Africa (MENA) region. Extending this research line, the analysis scrutinizes the impact of GVCs participation on ENS in 15 countries in MENA between 1996 and 2018. The study further investigates the moderating impacts of two major policy variables, namely Institutional Quality (IQ) and Digitalization (DIGI). The study employs SYS-GMM panel method and Random Effects. The empirical results indicate that GVCs participation is environmentally useful in the MENA region. The findings remain robust/similar when considering forward value participation linkages and oil-importing countries, whereas backward linkages deteriorate the region ENS. The findings further reveal that the GVCs environmental impact is modulated through IQ and DIGI. IQ and GVCs are particularly complementary in promoting ENS in MENA and across both oil importing and exporting groups. Nonetheless, the GVCs interaction with DIGI produces a negative net effect. This negative effect is mitigated beyond a particular threshold of 10.23%, necessitating complementary policies related to the link between GVCs participation and ENS below this threshold. Additionally, the findings affirm that FDI improves the environment, whereas natural resource rents degrade it, supporting the resource curse hypothesis for the MENA region. The study findings provide new insights into achieving improved GVCs integration while maintaining sustainable environment.

JEL classification: F18, Q56, C26

1. Introduction

It is becoming increasingly evident that climate change poses a series of threats to global environmental sustainability (ENS) and sustainable development (Nathaniel and Iheonu 2019). Currently, the COVID-19 crisis, economic uncertainty, the Ukrainian War, and concerns over energy security have all exacerbated the climate crisis. The Intergovernmental Panel on Climate Change (IPCC) alerts that we must halt burgeoning emissions immediately to prevent climate catastrophe (IPCC, 2022). To avoid the irreversible impacts of climate change, global temperature rise must be limited to 1.5°C above pre-industrial levels. Over the past century, humans have already warmed the planet by 1.1°C; and emissions are still rising (UN, 2022). In response, several countries have joined the global race to "net zero" (Agarwal et al., 2017) to achieve climate neutrality and keep the Paris Agreement 1.5°C target alive. Almost over 70 countries have enacted net-zero emissions targets, including the world's most polluting nations, accounting for approximately 76% of global emissions (UN, 2022). Moreover, approximately 85% of the world's population and 90% of its GDP are currently covered by net zero policies. However, according to UNFCCC report, given these countries commitments, the joint climate pledges of the Paris Agreement Parties could set the world on course for a warming of around 2.5°C by this century's end, along with 10.6% emissions rise by 2030 (UNFCCC, 2022).

On the other side, Global Value Chains (GVCs) have profoundly altered international trade structures, resulting in increased countries interconnectedness. Generally, the GVCs concept implies that different countries create a value-added to a product in the international production networks (Krugman, 1995). Global trade has expanded rapidly through GVCs, capturing over two-thirds of the world's trade in recent years (World Bank, 2020). Due to the rising importance of production sharing in the global economy, there has been recently a substantial debate over the GVCs environmental costs. The country participation in GVCs magnitude may influence the amount of carbon dioxide (CO2) emitted (Meng et al., 2018); as "Global supply chains play a critical role in many of the most pressing environmental stresses and social struggles" as highlighted by the United Nations' Sustainable Development Goals report. In the same vein, several studies revealed that international trade is responsible for 20–30% of overall CO2 emissions (Davis et al., 2011; Meng et al., 2018; Zhang et al., 2020). According to (Daudin et al., 2011), the GVCs sophistication has further complicated the understanding of the production cycle and, therefore determination of benefits and costs of participating in GVCs, and, as a result, formulating policies that allow governments to capitalize on GVCs while mitigating its adverse side effects, particularly their environmental impact. Parallelly, the advent of digitalization has profoundly altered the structure of GVCs, with implications for climate change.

The MENA region is comprised of a very heterogeneous group of countries. The region's wealth, social, and economic conditions vary considerably between and within countries. Oil-exporting countries with high incomes are juxtaposed with extremely poor countries (OECD, 2018). Even so, the MENA countries face common threats; political turmoil, population growth, poor governance, and oscillating oil prices, as well as climate change. The region is expected to experience almost twice as much warming as the rest of the world (Foreign Policy, 2021). Moreover, in the wake of the Net Zero epoch, the region's energy producing countries face further menaces as oil and gas export decline may harm their industries, destabilize rentier economies, budgets and erode social contracts.

the MENA region holds 59% of global oil reserves and 45% of global gas reserves, making it one of the world's major energy players (Lienard, 2022). Because of the abundance of nonrenewable resources, the region's energy mix is dominated by a one-sided reliance on fossil fuels which amplifies the risks associated with climate change.

Human activities in the MENA region are among the most carbon intensive in the world; despite accounting for little over 6% of the global population. The region emits approximately 13 tons of CO2 emissions per year, making it one of the largest emitters of greenhouse gases worldwide (see Fig. 1) (Lienard, 2022). Compared to other regions, MENA contributed only 5% of global GHG emissions in 2019.

Figure (1)

CO2 emissions/ capita in MENA vs. other regions

Source: Constructed by the authors using Climate Watch; tCO2e per capita: Tons of CO2 equivalent per capita

Recently, several MENA countries have committed to decarbonizing by 2050–2060, following the global commitment (e.g. Saudi Arabia and Bahrain pledged to decarbonize by 2060; Lebanon, the UAE, and Yemen pledged to decarbonize by 2050). Many countries also have submitted their updated (second) Nationally Determined Contributions (NDCs) to meet more ambitious climate goals. Nevertheless, MENA's progress on climate change is still limited.

Despite growing scientific interest in the global value chain and environmental sustainability (GVCs-ENS) nexus, empirical research investigating GVCs' impact on ENS is severely lacking. Moreover, the relationship between GVCs and ENS is contingent on a multitude of factors. Thus, a comprehensive understanding of this nexus complexity requires examining the moderating role of multiple factors, which has rarely been explored before. Therefore, this study aims at exploring the effect of GVCs participation on ENS measured by per capita CO2 emissions in MENA while accounting for digitalization (DIGI) and institutional quality (IQ) moderating impacts.

The study contributes to the extant body of knowledge in various aspects: (1) To the best of our knowledge, this is the first attempt to explore the impact of GVCs participation on ENS while accounting for DIGI and IQ moderating impacts. (2) This research examines the dynamics among the selected variables, with an emphasis on the MENA region, where both ENS and GVC participation are relatively significant; (3) Unlike earlier research that focuses on the CO2 embedded in GVCs, this is one of the few endeavors that uses the per capita CO2 emissions; (4) Previous work concentrated on the linear relationship between ENS and GVCs participation with minimal attention on the nonlinear relationship, this study explores the nonlinear relationship between the variables. (5) Ultimately, the paper takes into consideration both the backward and forward participation of GVCs.

A major motivation for this study is the fact that the MENA region represents an appealing case study; the region faces tremendous pressure in attaining the climate targets. The economic activities in MENA countries, on the other hand, are labor-intensive, highly energy-dependent, and pollutant-producing sectors; hence, their contribution to GVCs is accompanied by environmental pressure. Furthermore, the region has the lowest GVCs participation rate in the world (World Bank, 2020); and faces considerable governance and digitalization challenges. A flawed regulatory structure and poor governance are impeding regional value chain development in MENA, according to De Melo and Twum (2020). Thus, awareness of the potential modulating impacts of key variables such as DIGI and IQ are essential to the development of complementary policies and guidelines that can support industrial development, economic growth, international trade engagement, and environmental sustainability in MENA. The empirical findings of this investigation enrichs the existing literature and merit significant attention from MENA countries. Additionally, the study provides valuable conclusions that guide solid policy recommendations to enhance the environment quality while boosting the MENA's participation in GVCs.

The article content is divided into four sections: section one provides the existing literature and the hypotheses development, section two introduces the methodological techniques for data analysis; section three presents the results and discussion, and section 4 concludes.

2. Literature Review and Hypotheses Development

2.1. GVCs Participation and environmental degradation: The direct impact

Throughout this century, the ongoing debate has been over the prolonged growth in CO2 emissions (Liu and Xiao 2018). Ample literature investigated the association between CO2 emissions and its drivers in variety of countries and regions (e.g. Caglar et al., 2022; Shah et al., 2022; Aller et al., 2021; Jiang and Guan, 2019; Dogan and Seker, 2016). The emergence of GVCs, on the other hand, has significantly altered the international trade patterns and structures, causing an increase in interconnectivity through vertical/intra-industry linkages among producers in different economies (Assamoi et al., 2020). Arguably, for countries striving to develop and expand their markets, significant integration into GVCs is unavoidable. A major controversy has recently arisen over the environmental consequences of contributing to GVCs. As a result, a burgeoning body of research has focused on exploring these impacts, with however discordant findings.

Generally speaking, two distinct literature approaches have evolved in the relationship between GVCs participation and ENS. *The first approach* asserts that engagement in GVCs is environment-friendly, as enrolling in GVCs may assist in preventing environment pollution and deterioration and improve energy consumption. For instance, Wang et al. (2022) analyzed the dynamics between GVCs participation, CO2 emissions, and economic growth in a sample of 63 countries and regions. They concluded that participating in GVCs promotes long-term environment-friendly growth by increasing per capita GDP and lessening per capita CO2 emissions. Likewise, Maeno et al. (2022) proposed a framework to assess the impact of reorganizing Japan's auto supply chain with an emphasis on CO2 emission hotspots. They discovered that restructuring Japan's auto supply chain had the potential to lower CO2 emissions by 6.5% of the country's total carbon footprint. Assamoi et al. (2020) as well assessed the relationship between CO2 emissions and GVCs in 11 Asian countries. Their results indicate that higher GVCs participation reduces CO2 emissions. Similarly, Lui et al. (2018) proved that more GVC positions accounts for 35% of energy and environmental efficiency improvements in China.

The second approach contends that GVCs participation causes environmental degradation, as it can raise the energy consumption and simulate the carbon emissions through various means. For example, Ali and Gniniguè (2022) scrutinized the association between GVCs participation, structural transformation and environmental contamination in 41 African economies to determine whether African countries support environmental concerns while pursuing structural reform via GVC transformation. They conclude that participating in GVCs causes environmental damage. In a like vein, Qian et al. (2022) assessed the environmental impact of forward and backward GVCs. They highlighted that expanding GVC forward participation reduces CO2 emissions by improving production technology, whereas upgrading GVC backward participation increases CO2 emissions by increasing trade scale. Their analysis as well showed that forward participation in GVCs lowers emissions in home and neighboring countries while backward participation raises emissions in home countries. Likewise, participation in GVCs accelerates material and natural resource consumption, contributing to environmental degradation and resource depletion (Blank et al. 2018). According to (Golgeci et al. 2021) participation in GVCs entails a trade-off between long-term environmental benefits and short-term environmental costs. Eventually, GVCs can worsen environmental risks by transmitting adverse shocks both upstream and downstream (WTO, 2021).

Moreover, some scholars have provided evidence verifying the disparity in environmental costs between developed and developing countries when contributing to GVCs (i.e., high, and low income). Jin et al. (2022) and Shi et al. (2022) contended that developed countries reduce CO2 emissions by deepening their GVC participation, but developing countries raise it. Similar conclusions have been drawn by Duan et al. (2021) when considering the GVCs participation to prove the Pollution Haven Hypothesis. The authors argue that GVCs are also global pollution chains because high-income countries tend to export their emissions to low-income countries through outsourcing the dirty production stages only rather than the entire production process. Wang et al. (2019) evaluated the effect of GVCs contribution on per capita CO2 emissions using a panel set from 62 countries and regions. They deduced that nations with low GDP or low GVC participation levels are prone to have higher CO2 emissions in both the short and long terms. Based on our assumption that GVC participation benefits the environmental sustainability in MENA, we hypothesize that

H1

A positive direct (unconditional/ non-contingent) effect of GVCs on ENS exists in MENA

2.2. GVCs Participation and environmental degradation: The contingent/ indirect impact

In addition to the few existing studies that examine the direct impact, scholars have recently focused on investigating the indirect impact of GVCs on environmental sustainability. GVCs can indirectly influence the ENS through a variety of mechanisms.

Currently, *digitalization* and GVCs represent the most significant and revolutionary changes in international trade, with implications for climate change (Huang and Zhang, 2023; World Bank, 2019); as technological progress is linked to changes in a country's position in GVCs, as well as to its emissions level. Wang et al. (2019) asserted that more R&D spending has the potential to attenuate or even reverse the negative relationship between GVCs participation and CO2 emissions in a sample of five developing countries. They exemplify the existence of a value chain threshold; where participation in a value chain is lower than the threshold, technological progress can result in an increase in pollution; otherwise, technological progress can produce a reduction in emissions. Ye et al. (2020) investigated the impact of the technology gap on carbon intensity and positioning along GVCs. They show that narrowing the technology gap lessens a country's carbon intensity significantly. They reveal also that changing the position of the GVC affects the impact of the technology gap on carbon intensity. Ha and Thanh (2022) argued that, through facilitating knowledge and technology-sharing, GVC networks allow nations to acquire innovative knowledge and technologies, thereby improving ENS. The knowledge and technology sharing as well allows countries to expand their markets while maintaining environmental standards; it also facilitates consumer awareness of environmental requirements (Ha, 2022). On the contrary, several researchers have emphasized the negative externalities of GVCs digitalization, including the acceleration of climate change at the early stages of digitalization (Ha and Thanh 2022; Ha 2022).

On the other side, participating in GVC enhances the effectiveness of public rules and *institutions*, which are key to achieving environmental sustainability (Bartley, 2010; Ha and Thanh, 2022). Parallelly, GVC participation is significantly increased by improved institutions (Ge et al. 2020). According to Alhassan et al. (2020), institutional quality is critical in determining GVC engagement in Africa. Hong et al. (2020) reached that GVC participation is positively related to the quality of local institutions. In similar ways, macroeconomic factors such as the availability of a conducive business and institutional climate may influence country participation in GVCs, Amendolagine and colleagues (2019) report. However, (Golgeci et al. 2021) reported that a confusing relationship between GVCs participation and governance; as opportunistic behavior emerges due to the distinction between the environmental costs and benefits of GVC involvement, (Tolentino et al. 2016).

Such contradictions in research findings about the GVCs-ENS nexus and even in the effects of moderators themselves make it imperative for policymakers to develop reasonable and consistent strategies to expand their countries' participation in GVCs while conserving the environment. It also implies that a non-linear association between ENS and GVCs may exist, necessitating government awareness of critical levels of digitalization and institutional quality at which supplementary policies are required for GVC participation to be sustainable. Therefore, we argue that properly comprehending the effects of GVC participation on environmental sustainability requires an analysis of the moderating role played by DIGI and IQ. Accordingly, we propose the following hypothesis.

H2

GVCs participation effect on ENS is contingent on/ moderated by DIGI and IQ levels

2.3. Prior research in emissions determinants for MENA

Several attempts have been undertaken to detect the CO2 determinants in MENA region, focusing intensively, among other determinants, on the following: energy consumption (Alharthi et al., 2021; Cheikh et al., 2021; Charfeddine and Kahia, 2019; Farhani et al., 2014; Al-mulali et al., 2013); economic growth (Cheikh et al., 2021; Farhani et al., 2014); financial development (Charfeddine and Kahia, 2019); and urbanization (Sun et al., 2022; Al-mulali et al., 2013).

A recent contribution by Omri and Saidi (2022) examined the impact of renewable energy (REC) and non-renewable energy consumption (NRC) on CO2 emissions in 14 MENA economies. Their empirical results show a two-way relation between CO2 emissions and REC, as well as between CO2 emissions and NRC in both the short and long run. In a similar context, Sun et al. (2022) argued that urbanization and economic growth contribute to rising CO2 emissions, while REC is the best way to decrease them. Alharthi et al. (2021) provided a statistical validation for EKC in MENA; they also show that REC reduces CO2 emissions significantly, whereas NRC raises CO2 emissions. Eventually, Nathaniel et al. (2020) found that financial development, economic growth, and urbanization all contribute to environmental deterioration. REC, on the other hand, has no significant impact on environmental integrity, whereas NRC has a significant impact on environmental deterioration.

Despite its rapid evolution and growing popularity, GVCs is rarely considered when analyzing factors influencing CO2 emissions in MENA. Among the very few studies, Wu et al. (2020) studied the dynamic causality between GVCP, REC, and CO2 emissions for 172 countries between 1990 and 2015. Their findings indicated that, in contrast to other regions, REC and GVCP are positively correlated in MENA. Guedidi and Baghdadi (2020) explored the link between CO2, environmental provisions in regional trade agreements, and regional GVCs. They opined that MENA countries' participation in backward GVCs exacerbates environmental degradation.

Research gap

The empirical research on GVCs-ENS, as reviewed in the preceding subsections, revealed four deficiencies. One, previous research focused primarily on investigating the linear relationship between GVCs and CO2 emissions; and they are even sparse. Two, the extant research does not underline the significance of focusing on the moderating effects of critical policy variables such as DIGI and IQ. Third, the literature shows that GVCs play an increasingly significant yet dual and multilayered role in environmental sustainability (Golgeci et al. 2021). Therefore, this paper supplements these contradictory findings by examining the moderating role of IQ and DIGI that may explain and elucidate the convoluted link between GVCs and ENS. Ultimately, there is a severe lack of a coherent picture in research related to the GVCs-ENS relationship in MENA countries. Therefore, this inquiry reimburses for these shortcomings by empirically investigating the heterogeneous impacts of the selected moderating variables in GVCs and CO2 association for a set MENA country, thereby persuading different nations to develop differentiated carbon-reduction policies.

3. Materials and Methods

3.1. Empirical model

The study endeavors to examine the direct and indirect impacts of GVCs participation on ENS measured by per capita CO2 emissions in 15 MENA countries, namely: Algeria, Bahrain, Egypt, Iran, Iraq, United Arab Emirates, Saudi Arabia, Morocco, Tunisia, Jordan, Lebanon, Oman, Kuwait, Syria, and Qatar during the period 1996–2018. The availability of data for a balanced panel dictates both the countries and sample size selection. The analysis considers two policy variables that can modulate the GVCs effect on the ENS in MENA: IQ and DIGI. The primary research inquiry is: How will digitalization and institutional quality moderate/ affect the relationship between GVCs and ENS? The study follows the World Bank classification of MENA countries. Additionally, consistent with the literature and with the MENA countries case, where there are high levels of urbanization and FDI inflows as well as abundant natural resources. In addition to considering the rising concerns about the environmental impact of these factors in the region, we posit three different control variables: urbanization (e.g., Sun et al., 2022 and Anwar et al. 2022), natural resources rents (e.g. Calger et al. 2022; Azam et al. 2022; Li et al, 2021; Shen et al. 2021), and FDI (Abdouli and Hammami, 2017; Guoyan et al. 2022).

To explore the GVCs participation, IQ and DIGI joint impact on ENS, the study follows recent contribution by (Ali and Gninigu, 2022) and consistent with the existing literature (Al-Smadi, 2022; Lassoued, 2021; Bahrini and Qaffas, 2019), we apply the following standard two-steps system GMM procedures in levels (Eq. 2) and difference (Eq. 3) respectively. The SYS-GMM, unlike other traditional panel techniques, as it can tackle the issue of county-specific effects.

$$\mathrm{ENS_{it}} = \mathrm{f(GVCP, GVCP^2, IQ, DIGI, NRC, URBPOP, NRR, FDI)}$$ Eq. (1)

$$ENS_{it} = \beta_0 + \beta_1 GVCP_{it} + \beta_2 GVCP^2{}_{it} + \beta_3 IQ_{it} + \beta_5 DIGI_{it} + \beta_6 URPOP_{it} + \beta_7 FDI_{it} + \beta_8 NRR_{it} + \beta_9 NRC_{it} + \epsilon_{it}$$

$$\mathrm{ENS_{it}} = \alpha_0 + \alpha_1 \mathrm{ENS_{i(t-\tau)}} + \alpha_2 \mathrm{GVCP_{it}} + \sum_{h=1}^{k} \delta_h X_{h,i(t-\tau)} + \vartheta_t + \mu_i + \epsilon_{\mathrm{it}}$$

Eq. (2)

$$\mathrm{ENS_{it}} - ENS_{i(t-\tau)} = \alpha_1 \left(ENS_{i(t-\tau)} - ENS_{i(t-2\tau)}\right) + \alpha_2(\mathrm{GVCP_{it}} - \mathrm{GVCP_{i(t-\tau)}}) + \textstyle\sum_{h=1}^{k} \delta_h (X_{h,i(t-\tau)} - X_{h,i(t-2\tau)})(\vartheta_t - \vartheta_{t-1}) + \epsilon_{\mathrm{i(t-\tau)}}$$
Eq. (3)

Where GVCP and GVCP^2 depict the global value chains participation and its square respectively. The equation involves adding the square of GVCs participation to investigate the Environmental Kuznet Curve (EKC) hypothesis in the sample. ENS is environmental sustainability measured by CO2 emissions (MtCO2), IQ indicates institutional quality, DIGI depicts the digitalization level, NRC indicates non-renewable energy consumption, NRR refers to natural resources' rents, URBPOP is the urban population (% of total population), and eventually FDI is for foreign direct investment inflows. Where i is the cross section (15 MENA countries) and t are time dimensions (1996–2018); ϵ is the error term as well as δ is the time invariant constant. $\mu$is the country fixed effects. The digitalization index (DIGI) in the equations is calculated using principal component analysis (PCA) based on access to internet and mobile phone subscribers (Ali and Gniniguè, 2022). More details are provided in Table A-1 of the appendix.

To test for the moderating impact of IQ and DIGI, the following econometric model with multiplicative interaction terms on IQ and DIGI is proposed:

$$ENS_{it} = \vartheta_0 + \vartheta_1 GVCP_{it} + \vartheta_2 GVCP^2{}_{it} + \vartheta_3 IQ_{it} + \vartheta_5 DIGI_{it} + \vartheta_6 (GVCP * IQ) + \vartheta_7 (GVCP * DIGI) + \vartheta_8 URPOP_{it} + \vartheta_9 FDI_{it} + \vartheta_1$$
Eq. (4)

Calculating the participation in GVCs

Due to the lack of direct measurement of GVCP for each country, the study follows the previous research (e.g., Casella et al., 2019; Aslam et al., 2017) in adopting the Koopman et al. (2014) method of measuring the index as follows:

$$ForwardValueChainparticipation_{it} = \frac{IndirectValueAdded\,(DVX_{it})}{TotalExports_{it}}$$

$$BackwardValueChainparticipation_{it} = \frac{ForeignValueAdded\,(FVA_{it})}{TotalExports_{it}}$$

$$GVCsparticipation_{it} = \frac{FVA_{it} + DVX_{it}}{TotalExports_{it}}$$

Where i refers to country, t is time.

3.2. Variables and Data Source

A dataset for this paper spans 15 countries and encompasses eight variables: one dependent, three independent, two moderators, and three controls. Detailed information on the variables' positions, measurements, and sources can be found in Table (1) below:

Table 1
Data Definitions, Sources and Descriptive Statistics

Variable	Abb	Position	Measurement	Obs.	Mean	SD.	Past Used	Source
Global Value Chains (% of total exports)	GVCs	IV	FVA + DVX	345	0.273	4.465	Ha and Thanh, 2022; Alhassan et al. 2020	UNCTAD-Eora
Foreign Value Added (Backward-Upstream participation)	FVA	IV	% of total exports	340	.038	.559	Ha and Thanh, 2022; Alhassan et al. 2020	UNCTAD-Eora
Indirect Value Added (Forward-Downstream participation)	DVX	IV	% of total exports	345	.233	3.911	Ha and Thanh, 2022; Alhassan et al. 2020	UNCTAD-Eora
CO_2 Emissions per capita	ENS	DEV	MtCO2	345	12.247	13.696	Sun et al. (2022); Rahman et al. (2022)	GCP
Digitalization **(%)**	DIGI	Moderator	Computed	340	0	1.368	Ali and Gniniguè (2022)	WDI
Institutional Quality	IQ	Moderator	Average of World Governance Indicators	300	− .35	.632	Nchofoung and Asongu, 2022; Ngouhouo et al. 2021	WGI
Urbanization	URP	Control	Urban Population % of total population	345	74.457	16.032	Sun et al., 2022; Al-mulali et al., 2013	WDI
Foreign Direct Investment	FDI	Control	Foreign Direct Investment, Net inflows (% of GDP)	337	2.754	3.831	Abid et al. (2022); Shahbaz et al. (2018)	WDI
Natural Resources Rents	NRR	Control	Total Natural Resources Rents (% of GDP)	345	20.574	17.061	Adebayo et al. (2022); Gyamfi et al. (2022)	WDI
Non-renewable energy consumption	NRC	Control	Quad Btu	345	.185	.46	Omri and Saidi, 2022; Alharthi et al. 2021; Nathaniel et al. 2020	EIA

Note: WDI = World Development Indicators; GCP = Global Carbon Project; EIA = Energy Information Administration; UNCTAD = United Nations Conference of Trade and Development; IV = independent variable; DEV = Dependent variable; SD = standard deviation

GVC participation in the MENA region makes up only 27.3% of its total exports; emphasizing the fact that MENA has the lowest participation rates in GVCs worldwide (World Bank, 2020). The region has a relatively low backward participation rate (3.8%), compared to the forward participation rate (23.3%). Moreover, MENA countries' backward participation has declined since 1996, in contrast to their forward value chain participation. Conflicts, fragile conditions, and an absence of political stability are the major obstacles to backward GVC participation in MENA (World Bank, 2020). On average, the region emits 12.247 MtCO2, making it one of the world's highest emitters. The urban population accounts for approximately 75% of the total population of the region. FDI, on the other hand, accounts for approximately 3% of its GDP. Competition obstacles, skills gaps, weak infrastructure, governance problems, and sluggish regional integration all contribute to FDI's tiny share of GDP. More so, the health and economic crises engendered by the Covid-19 pandemic, as well as global and regional conflicts and disruptions, accentuate the decline in FDI in the region (OECD, 2021). Table (1) also shows the NRR's significant share of total GDP (20.6%).

4. Empirical Findings and Discussion

The study entails the execution of six models. Tables (2) and (3) display the findings of the empirical investigation. The first table employs the dynamic panel two-step SYS-GMM model, while the second employs the random effect (RE) model. For Table 2, Model 1 depicts the GVCs participation unconditional impact on ENS; Models 2, 3 and 4 present the Global, Backward and Forward value chains participation impact on ENS contingent on DIGI and IQ, respectively. Nevertheless, Models 5 and 6, shown in Table 2, present the conditional impact of GVCs on ENS for oil exporting and oil importing countries, respectively.

Overall, the SYS-GMM findings demonstrate that CO2 emissions levels are heavily influenced by their previous values at the 1% level, implying that increased emissions from the previous year drive up current year emissions.

For the unconditional model, the GVCs participation coefficient is negative and significant at 1%. The results further affirm the existence of a U-shaped EKC nexus between GVCs participation and ENS. This U-shaped relationship signifies that GVC participation begins to crumble the ENS after a certain threshold; this is not the case in the presence of the DIGI and IQ conditional impacts, where the GVCP square is insignificant and thus the EKC hypothesis does not hold. Additionally, FDI has a significant positive impact on environmental sustainability in MENA at the 1% level. Conversely, natural resource rents, and institutional quality have a positive association with CO2 emissions, highlighting their adverse environmental impacts. Digitalization, urbanization, and non-renewable energy have insignificant impact.

Likewise, the GVC participation coefficient in the conditional model (Model 2) is negative and significant at 5%. When the moderating variables are included, the coefficient becomes even more significant, demonstrating the positive impacts of GVC participation on the environmental sustainability in the MENA region. Several studies corroborate our conclusions. For instance, Wang et al. (2022) opined that GVCs participation stimulates environmentally friendly growth in the long run through increasing GDP per capita and lowering CO2 emissions per capita; as well as Assamoi et al. (2020) in the context of selected Asian countries.

As previously stated, the model results do not support the EKC hypothesis between GVCs participation and CO2 emissions in MENA. FDI retains its environmentally beneficial impact. Therefore the Pollution Haven Hypothesis is invalid for MENA. This is largely consistent with previous studies (Demena and Afesorgbor, 2020; Hao and Lui, 2015). NRR also harms ENS, proving the resource curse hypothesis in the region. The outcomes support the prior works of (Lui et al. 2023; Tufail et al. 2021; Shen et al. 2021).

Regarding interaction, the findings show that the impact of GVCs participation on ENS is modulated by IQ and DIGI levels. On the one hand, IQ and GVCP interaction term produce a positive effect. This suggests that the quality of institutions enhances the positive impact of GVC participation and that the two are complementary in attaining environmental sustainability in MENA. On the other hand, DIGI and GVCP interaction, on the other hand, generates a negative effect on ENS. Our results are supported by Yang and Liu's (2021) findings that the interaction of R&D and GVC positions increase environmental pollution by driving up CO2 emissions. They further attributed this detrimental effect to a demotivation among industrial sectors to increase R&D spending to reduce CO2 emissions; therefore, a substitution effect between GVC position and R&D spending may occur. Considering MENA's low integration in GVCs, these findings also align with recent work by (Huang and Zhang, 2023), which conclusively proved that countries with a high GVC position find it easier to accomplish reductions in carbon emissions embodied in exports through digitalization.

Following the recent contributions by (Nchofoung et al. 2021; Achuo et al. 2022), the sign alteration between the direct and indirect impacts of DIGI is an adage for the presence of net effects; and hence it is imperative to calculate the net effect of GVCP on ENS as follows.

$$NetEffect = \left\{ \begin{array}{c} \alpha_1 + (\gamma^* \beta_i)\, if \alpha_1 and \beta_i have oppisite signs but both are significant \\ N.A. if \alpha_1 and \beta_i have the same sign or at least \alpha_1 or \beta_i is insignificant \end{array} \right\}$$

β_i denotes the magnitude of the indirect effect; γ is the mean value of the moderating variable; and N.A denotes not applicable (i.e., the net effect cannot be computed); and consequently, the policy modulatory variable threshold can be computed as follows:

Threshold = $\left| \frac{unconditionalimpact}{conditonalimpact} \right| = \left| \frac{\alpha_1}{\beta_i} \right|$

The net effect is -0.496, implying that the direct effect negates the indirect effect, yielding a negative net effect. Above a certain DIGI threshold, this negative net effect is eliminated. In other words, the GVCP can only improve the environment above a certain DIGI threshold. Following pertinent calculations, a threshold value of 10.23% is obtained. This value implies that for GVCP to be environmentally beneficial, digitalization must be higher than 10.23%. Complementary policies are required to maintain positive net effects on ENS below the established threshold. Not to mention, the region should indeed expedite its digitalization in order to reap the benefits of participating in global value chains, particularly environmental ones. A compatible conclusion was drawn by Wang et al. (2021), who discovered that there is a threshold; technological progress can result in an increase in pollution where participation in a value chain is below the threshold; otherwise, technological progress can result in a decrease in emissions.

In a similar fashion, participation in backward (Model 3) and forward (Model 4) value chains have different environmental consequences. The integration of MENA countries into backward value chains, like global value chains, contributes to their sustainability. At 5%, MENA participation in backward (downstream) value chains has a statistically significant and positive impact on environmental sustainability. In contrast, MENA insertion into forward value chains degrades its environmental quality at 5% level. These findings are in line with the results of (Guedidi and Baghdadi, 2020), who found that when MENA countries participate in forward GVCs in the Low-Tech Manufacturing sectors, the environment deteriorates, whereas backward GVC participation in the presence of regional trade agreements improves the region's environmental quality. However, our findings contradict Qian et al. (2022) in the Regional Comprehensive Economic Partnership (RCEP) countries context, who found that expanding GVC forward participation reduces CO2 emissions, whereas upgrading GVC backward participation increases CO2 emissions. On the other side, IQ remains to complement the backward integration in improving environmental quality. In forward integration case, however, both modulatory variables are insignificant.

To verify the reliability of the previous results, residuals should not exhibit either first- or second-order autocorrelation. In the results shown in Table (2), AR1 has p-values lower than 10%, while AR2, denoting the second order, has p-values higher than 10%.

Table 2
Conditional and Non-conditional impact

Variables	Model (1) Unconditional	Model (2) GVCs participation	Model (3) Backward Participation	Model (4) Forward Participation
ENS = L,	0.871***	0.854***	0.835***	0.866***
	(0.026)	(0.038)	(0.044)	(0.035)
GVCP	-0.42250**	-0.52077***		
	(17.501)	(15.015)		
GVCP2	3.58876**	-1.79482		
	(174.643)	(129.385)		
FVA			-2.99121**	
			(137.501)	
FVA2			44.81956	
			(6,626.103)	
DVX				0.39366**
				(16.317)
DVX2				1.31232
				(177.53)
URP	0.022	0.029	0.025*	0.023
	(0.015)	(0.020)	(0.015)	(0.020)
FDII	-0.066**	-0.085**	0.005	-0.075**
	(0.027)	(0.038)	(0.025)	(0.036)
NRR	0.032***	0.039***	0.029***	0.038***
	(0.008)	(0.011)	(0.009)	(0.010)
NRC	0.057	-0.238	-0.232**	-0.111
	(0.203)	(0.307)	(0.107)	(0.262)
IQ	1.282***	3.111***	2.608***	1.883**
	(0.447)	(0.876)	(0.772)	(0.747)
Digi	-0.040	-0.496*	-0.185	-0.213
	(0.064)	(0.278)	(0.171)	(0.179)
GVCP_IQ		-0.80406***		
		(19.809)		
GVCP_DIGI		0.16277**		
		(7.018)		
FVA_IQ			-2.30373***	
			(72.160)	
FVA_DIGI			0.31707	
			(26.684)	
DVX_IQ				-0.32294
				(20.696)
DVX_DIGI				7.604
				(4.822)
Constant	0.525	0.593	1.411*	0.214
	(0.687)	(0.841)	(0.784)	(0.933)
Observations	276	276	274	276

Variables	Model (1) Unconditional	Model (2) GVCs participation	Model (3) Backward Participation	Model (4) Forward Participation
Number of c_id	15	15	15	15
AR1 P-value	0.047	0.042	0.051	0.045
AR2 P-value	0.142	0.141	0.145	0.144
Sargan P-Value	0.156	0.173	0.153	0.160
Hansen P-value	0.552	0.501	0.503	0.532

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

Source: Authors' computation

Models (5) and (6) in Table 3 utilize the random effect method to showcase the GVCs participation impact on environmental sustainability as well as the IQ and DIGI moderating impacts for oil-exporting and importing countries in MENA respectively. As shown in Table 3, the GVCP remains its favorable environmental impact in oil exporting countries, although it is insignificant in oil importing countries. Urbanization also continues to worsen the environmental quality in both oil importing and exporting countries; with the negative impact is more in oil exporting countries; a 1% increase in urbanization increases the CO2 emissions by 6.7% and 1% in oil exporting and oil importing countries, respectively. This is consistent with (Gaies et al. 2022) results for MENA net-exporting countries compared to importing countries, where urbanization has a negative environmental impact. It is worth noting that nearly two-thirds of MENA's population live in cities, far exceeding the global average of just over half. It is predicted that this rate will increase even further, rendering the region to be one of the most densely urbanized worldwide (Fawaz, 2021).

Furthermore, FDI has a negative impact on the environment in oil-producing countries, supporting the emergence of the Pollution Haven Hypothesis in these countries. The results agree with (Gyamfi, 2022), who deduced that FDI increases consumption-based carbon emissions by 0.0156 to 0.186% in oil-producing sub-Saharan African countries. In contrast, NRR improves environmental sustainability in oil-exporting countries. Both IQ and NRC are insignificant in oil importing countries. DIGI, on the other hand, has a positive impact on ENS across both groups, with the impact debuting to be stronger in oil-exporting countries. In terms of moderation, IQ interaction with GVCP continues to have a beneficial environmental impact in both groups of countries, demonstrating the robustness of our findings. DIGI interactive, on the other hand, has a positive relationship with CO2 emissions only in oil-importing countries. The significant modulatory variables in oil-importing countries, even though the GVCP in itself is not significant, suggest that the relevant complementary DIGI and IQ policies may potentially promote the GVCP's impact on environmental sustainability.

Table 3
Oil Exporting and Oil Importing countries

Variables	Model (5) Oil Exporting	Model (6) Oil Importing
GVCP	-2.29654***	-0.023038
	(0.73918)	(0.61030)
GVCP2	-1.49386	-4.10897
	(9.51338)	(11.25977)
URP	0.954***	0.038***
	(0.067)	(0.010)
FDI	-0.056	0.025**
	(0.137)	(0.011)
NRR	-0.084**	0.025
	(0.039)	(0.017)
NRC	1.838	-2.251
	(1.436)	(3.037)
IQ	7.071***	0.001
	(1.884)	(0.689)
DIGI	-2.030***	-0.299*
	(0.669)	(0.168)
GVCP-IQ	-1.89368**	-0.64448*
	(0.87185)	(0.34751)
GVCP-DIGI	-0.011126	0.012325*
	(0.23906)	(0.07021)
Constant	-49.146***	0.145
	(5.009)	(1.255)
Observations	190	100
Number of c_id	10	5

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

Source: Authors' computation

5. Conclusion and Policy Implications

The rapid proliferation of GVCs has raised concerns about their environmental impacts. Recently, GVCs have been inextricably tied to digitalization's rapid expansion, which is thought to offer a solution to climate change exacerbated by GVCs participation, particularly in developing countries. In the same way, institutional quality is gaining importance to ameliorate the adverse consequences of GVC participation. Therefore, the potential impact of digitalization and institutions on environmental impact stimulated by nations' integration into GVCs are worth exploring. As part of the ongoing debate over GVCs environmental ramifications, this study proposes a novel perspective on reconciling GVCs participation growth goal with the emissions reduction goal by embracing two major policy variables as potentially modulatory variables on the GVCs-ENS nexus. Consequently, this investigation discerns whether participating in GVCs is environmentally friendly in the MENA region, followed by examining the moderating impacts of two relevant policy variables: digitalization and institutional quality, on the GVCs-ENS linkage. To do so, we employed the system GMM on GVCs database from the United Nations Conference on Trade and Development (UNCTAD-EORA MRIO) for 15 MENA countries from 1996 to 2018. We also considered the environmental consequences of both the backward and forward value chains.

Empirical findings uncover that GVCs participation improves MENA's environmental quality. Participation in GVCs, however, has divergent polluting impacts based on backward or forward integration. Forward linkages have favorable environmental impacts, while backward linkages degrade environmental sustainability. Similarly, GVCs participation has different environmental impacts in oil-importing and oil-exporting countries, with participation in value chains enhancing oil-importing countries' environmental quality while having an insignificant impact on oil-exporting countries' ENS. These discrepancies in findings between oil and non-oil MENA countries allow positing distinct policies for these two groups of countries. Evidently, the findings demonstrate that GVCs environmental impact is modulated through IQ and DIGI. In one sense, IQ and GVCs are particularly complementary in promoting ENS in MENA and across

both oil importing and exporting groups. GVCs and DIGI, on the other hand, are substitutes for improving the quality of MENA's environment, with their interaction generating a negative net effect. Fortunately, this negative effect is reversed above a threshold of 10.23%. Consequently, supplementary policies regarding GVC participation and ENS below this threshold are essential, in tandem with policies to improve digitalization and to reap the environmental advantages associated with higher participation in GVCs. Generally, FDI can mitigate CO2 emissions significantly, while natural resource rents increase them, supporting the resource curse hypothesis for MENA.

Our results suggest that to achieve a "win-win" situation of higher GVCs participation and environmental sustainability, MENA economies have to consider digitalization and IQ levels when formulating export policies and strategies. On the one hand, low digitalization levels in the region, according to the model results, hinder the favorable environmental impact induced by higher GVCs values. Thus, policies aimed at increasing digitalization are of the utmost importance. Broadband unaffordability, lack of digital skills, outdated and insufficient infrastructure, and strict government regulations are all digitalization barriers in the region (the Wilson Center, 2022). Additionally, notwithstanding its evident positive impact, the government's relentless pursuit of digital transformation is critical for ensuring a positive impact of digitalization on GVCs participation (Ha, 2022). Therefore, robust, and supportive policies facilitating digitization adoption must be implemented.

Undoubtedly, MENA countries are entangled in an inexorable circle of poor digitalization and limited productive capacity, inhibiting their participation in high-value-added production owing to low human capital levels. Investment in human capital is therefore indispensable for better positioning of GVCs. On the other hand, a well-structured institutional system is also essential to emphasize the environmental benefits associated with higher GVCs participation in the MENA region.

Moreover, despite its environmental improvement impact, the relatively higher integration in forward linkages compared to backward linkages suggests that MENA's exports contain lesser intermediate imports, which cater as a channel for improving and transferring technology, innovation, and know-how. Likewise, the high level of integration in forward linkages implies that raw materials and agricultural products (less sophisticated products) account for most of the region's exports (Melo and Solleder, 2022). Therefore, to accelerate its exposure to more digitalized and innovative production (more sophisticated) necessary for its structural transformation, the MENA region needs to boost its involvement in backward value chains by removing trade barriers and lowering trade costs.

This study sample is limited due to a lack of data on some countries. The study also focuses on CO2 emissions as an indicator of environmental sustainability. Future research, therefore, may focus on applying the approach to a broader set of countries (e.g., developing countries) or using other environmental sustainability metrics.

Abbreviations

GVCs	Global Value Chains
ENS	Environmental Sustainability
ICT	Information and Communication Technology
CO2	Carbon Dioxide
MENA	Middle East and North Africa
REC	Renewable Energy Consumption/ Usage
NRC	Nonrenewable Energy Consumption/ Usage
NRR	Natural Resources Rents
IQ	Institutional Quality
DIGI	Digitalization
FDI	Foreign Direct Investment

Declarations

Ethical approval and consent to participate

The authors declare that there are no human participants, human data, or human issues.

Consent for publication

All authors have agreed to publish

Consent to participate

The authors voluntarily agreed to participate in this study.

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Competing interests

The authors declare no competing interests.

Data availability

The authors confirm that data will be made available upon reasonable request.

Contributions

The two authors contributed to the study conception and design. **Prof. Dr. Suzanna Elmassah:** writing- review, revision and editing- analysis, supervision; **Eslam A. Hassanein:** methodology and analysis, investigation, writing- first draft.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

NA

Suzanna Elmassah on behalf of all authors

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Figures

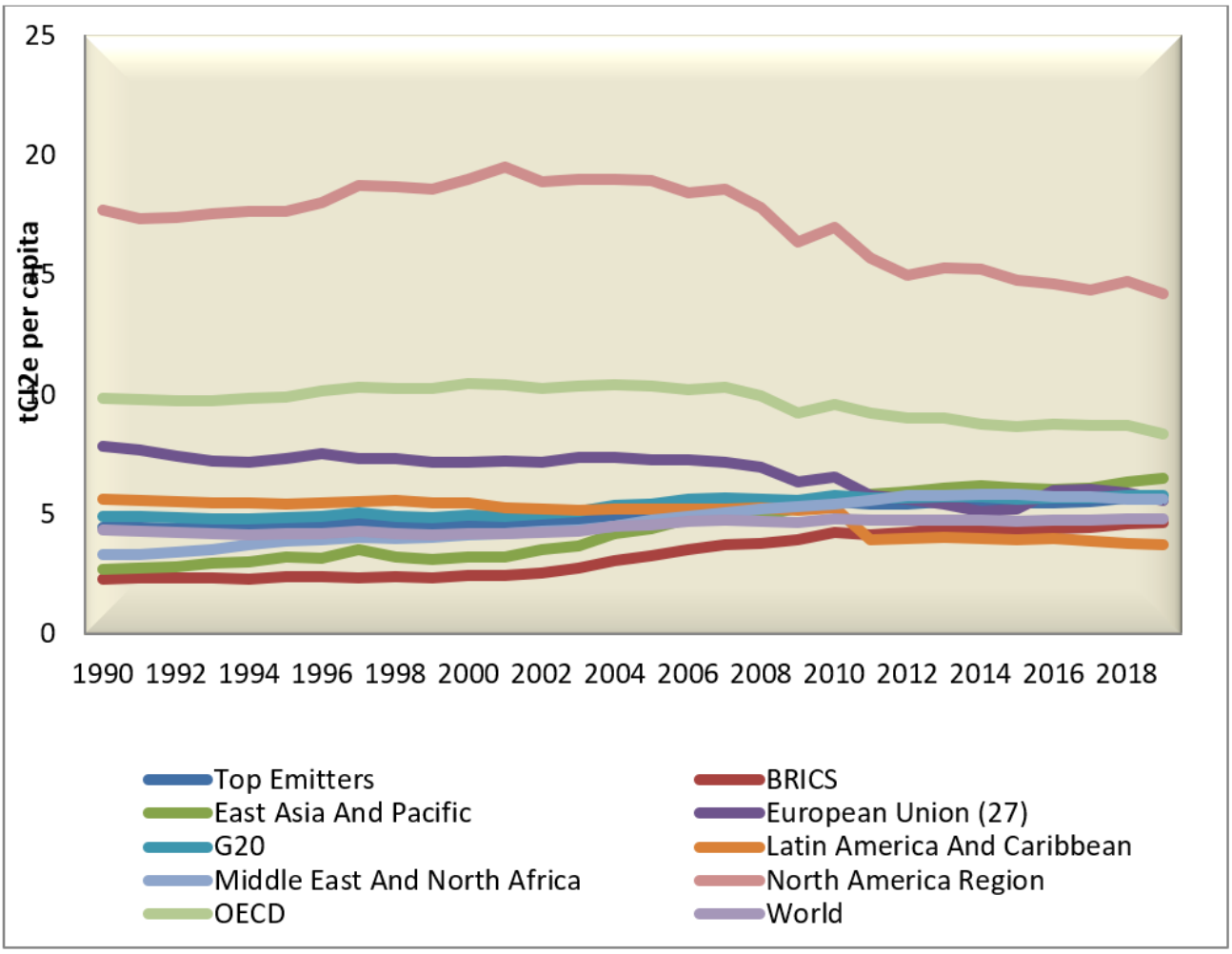

Figure 1

CO2 emissions/ capita in MENA vs. other regions

Source: Constructed by the authors using Climate Watch; tCO2e per capita: Tons of CO2 equivalent per capita

Supplementary Files

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- Appendix.docx