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THE IMPACT OF DIGITALIZATION AND ECONOMIC DIVERSIFICATION ON ECONOMIC GROWTH: EVIDENCE FROM SAUDI ARABIA

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Abstract. The present study aims to assess the impact of economic diversification and digitalization on economic growth in Saudi Arabia during the period 1990–2021. We have looked into this relationship in both the overall economic and non-oil economic sectors using the autoregressive distributed lag (ARDL) cointegration approach. The empirical results offer compelling evidence that economic diversification and digitization affect economic growth both directly and indirectly through their effects on non-oil GDP growth. The findings indicate that there is a long-run dynamic between economic growth, economic diversification, and digitalization. In the long run, digitalization contributes to the progress of non-oil economic growth and, therefore, sustainable economic growth. In addition, the causality test revealed that economic diversification develops the economy of new knowledge, which reinforces economic diversification, and non-oil economic growth supports digitalization. Consequently, digitalization played an important role in the Kingdom's economic transition toward economic diversification. Indeed, our results prove that digitalization increases non-oil income and then reduces the supremacy of the oil sector in the economy, which promotes economic diversification. The KSA authority must accelerate the energetic transition process in order to support economic diversification and attract more foreign investment in information and communication technologies (ICTs).

Keywords: digital economy, digitalization, diversification, economic growth, ARDL model.

JEL Classification: O11, O33, O47.

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1. Introduction

Development is the top concern of all world economies. All nations try to develop their economies in order to achieve their sustainable development. This development can be realized in two ways: quantitatively and qualitatively. Quantitatively, it is usually related to economic diversification. Because economic diversification is essential for growth. By diversifying its economy, a nation has a great possibility of achieving all of its economic objectives. Economic diversification is an important step in a nation's development since it results in a more diversified structure for investment, production, service, and trade. It remains a challenge for most developing countries, perhaps even more so for low-income countries, small countries, landlocked countries, or those whose economies are highly dependent on energy resources. For these countries, economic diversification is closely related to the structural transformation of their economies and the rising levels of production and productivity resulting from

the movement of economic resources within and between different economic sectors of the economy.

Qualitatively, due to the development of information and communication technologies (ICTs), the productivity of workers and firms has experienced a permanent increase. Indeed, since the industrial revolution conducted by technical progress, many economies of countries have experienced remarkable growth (Arsić, 2020; Ha & Peter Chuah, 2023). Moreover, Zhou (2023) indicated that digitalization increases the consumption of rural households in China. The main goal of this ICT development is the digitalization of economic activities in all sectors. This can later solve numerous problems in the economy, such as slowdown of productivity, excess use of workers, speed of data transfer, storage of data, etc. So, digitalization can support the sustainable development of any country.

Overall, in reality, both economic diversification and digitalization contribute quantitatively and qualitatively to economic growth. For this reason, nowadays all countries look for all factors that can promote economic diversification and digitalization. Among all these countries, the energy-rich countries, especially those with non-renewable energy, are the ones most affected by the problems of the lack of economic diversification and digitalization. Natural resources, especially the sources of non-renewable energy, are limited and will eventually be exhausted. They are also a source of a variety of regional, national, and international challenges and pressures. Oil-rich countries have long since started to look for alternative economic resources to lessen their vulnerability to the effects of oil price fluctuation, the interference of various parties, and factors in the distribution of oil revenues. For all these reasons, it is crucial for oil-rich countries to invest in technologies and diversify their economies. KSA as one of the main petroleum countries is concerned with the economic diversification and digitalization process. It has begun to develop the ICT and economic diversification infrastructure for many years and this development accelerated with the 2030 vision established in 2016. We believe that it's time to test the results of these developments. In this study, we will analyze the impact of digitalization and economic diversification on the KSA economy.

The rest of the paper is organized as follows: Section 2 presents a brief description of economic diversification in the Kingdom of Saudi Arabia (KSA). We review related literature on the contribution of economic diversification and digital transformation to economic growth in Section 3. Section 4 investigates the data and measurement and outlines the appropriate research methodology for economic diversification and digital transformation. Section 5 presents and discusses the findings. Finally, Section 6 provides a conclusion and policy implications.

2. Economic diversification in KSA

Economic diversification has become one of the main issues in oil-producing countries worldwide. Saudi Arabia is one of the most famous countries in the oil and energy markets. It is the second-biggest country in terms of the global production of crude oil. It is ranked sixth in the world in proven gas reserves (22% of global proven gas reserves) (Al Naimi, 2022). From these statistics, one can believe that the economy of Saudi Arabia can realize sustain-

able economic growth through job creation. Economically, this can be conducted with the revenue from oil exportation. However, as with other energetic countries, Saudi Arabia needs government intervention to achieve sustainable economic growth.

Many countries suffer difficulties in their economies because of the supremacy and dominance of the energy sector in the economy (resource-dependent countries). Indeed, in these countries, revenue comes essentially from the energy sector. The economic theories explained this situation mainly through the Dutch disease model and fluctuations in energy prices. All studies in this field arrive at the same conclusion: these economies (Saudi Arabia, Bahrain, Iraq, Qatar, Kuwait, and Libya) suffer from a lack of economic diversification. Then, economic diversification constitutes an important challenge for these petroleum economies. Figure 1 below presents the export diversification of Middle East and North Africa (MENA) countries.

International institutions, such as the World Bank and the International Monetary Fund (IMF), encourage policymakers and governments of these countries to investigate more non-oil sectors such as tourism, agriculture, and especially technology. Indeed, as indicated by Al-Roubaie (2019) and Jurayevic and Bulturbayevich (2020), the development of science and technology (digitalization) is an important factor in growing labor productivity and economic growth. Today, because of digital networks, information can easily and quickly circulate between regions and countries. This is providing new opportunities for all, especially unfavorable regions in countries, to produce and contribute to economic wealth. On the other hand, digitalization can reduce costs and corruption in countries, notably in those rich in natural resources. Indeed, in the digital economy, transactions are controlled. These transactions are conducted through networks linking all parties (enterprises, institutions, governments, etc.). Overall, digitalization can create new job opportunities and accelerate economic diversification.

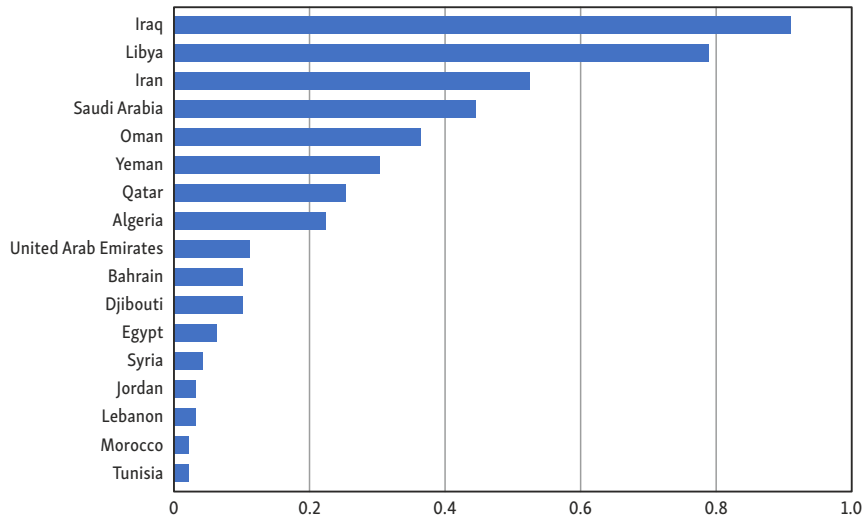


Figure 1. Export diversification (HHI) – Middle East and North Africa (2017) (source: OECD/World Trade Organization, 2019)

There are many definitions of diversification. At the microeconomic level and from a company's perspective, we must distinguish between vertical and horizontal diversification. Horizontal diversification means that the company creates a new activity similar to its original activity. Vertical diversification is manifested by the launch backward or forward of new activity in the main sector of activity. At the macroeconomic level and from a global economic perspective, diversification means that many sectors contribute to economic growth. A diversified economy works with many sectors, not only one. Economic and Social Commission for Western Asia [ESCWA] (2001) defines economic diversification within the context of the Gulf Cooperation Council (GCC) countries as reducing the degree of dependency on the oil sector or export by developing the non-oil sector, non-oil export, and non-oil revenues. In this study, we are interested in economic diversification at the macroeconomic level.

The Kingdom of Saudi Arabia (KSA), as a major oil producer, is also concerned about economic diversification. KSA has started economic diversification since 1970, as indicated by Al Naimi (2022), but, for some years (since 2016), KSA has accelerated a series of reforms under a program named KSA 2030 Vision (Kingdom of Saudi Arabia, 2020). This vision is based on the following three principles: a vibrant society, a thriving economy, and an ambitious nation. The main objective of these three principles is to diversify the economy of KSA through the multiplication of sources of revenue. Compared to other oil producers, KSA has an advantage in the tourism sector. Indeed, one important way of diversifying revenue sources is to increase the tourism sector by increasing the number of Islamic tourists who are tourists for Umrah and Haj. Moreover, the KSA government has increased value-added tax (VAT) by 200% in 2020. Another important way that Saudi Arabia must develop it to decrease their dependence on oil is to accelerate investigations in the non-renewable energy sector (solar, wind, etc.).

Figure 2 below shows the evolution of the contribution of each sector to the production of KSA. The main conclusion that we can draw from this figure is that the industry and service

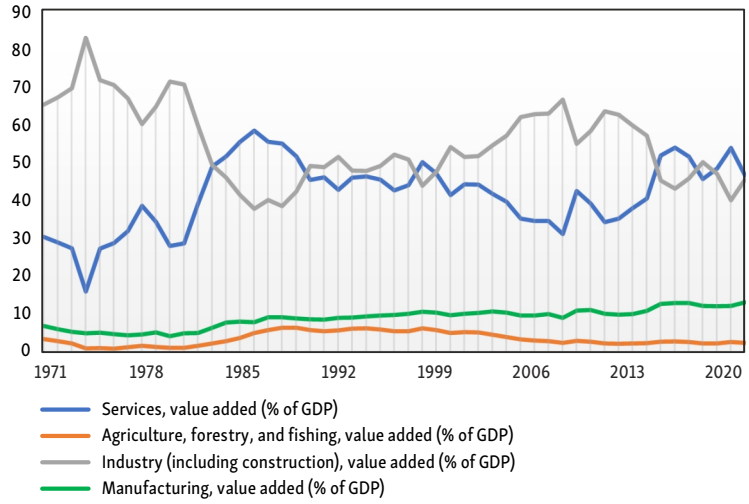


Figure 2. Contribution of economic sectors value added to GDP in KSA (source: authors' elaboration, from General Authority for Statistics, 2023)

sectors are the main contributors to KSA's economic growth. In 2013, the contribution of the services sector to GDP (gross domestic product) increased significantly, while the contribution of the industry sector decreased. Agriculture and manufacturing remain the two smaller contributors to KSA's GDP.

There are many benefits to economic diversification. Euchi et al. (2018) indicated that economic diversification creates jobs, reduces poverty, and improves life and institutions' qualities. Gylfason (2017) considers that the benefits of economic diversification can be viewed through the economic difficulties as described by Dutch disease theory in countries rich in natural resources, known as the "resource curse". This means that economic diversification can remove all the difficulties of the resource curse.

In Saudi Arabia, economic diversification is a top priority in the process of transformation. It gives many benefits, such as resilience to external shocks, promoting entrepreneurial cases, and developing the national skills base, among others. Overall, the main target of economic diversification in Vision 2030 seeks to move the Saudi economy toward a sustainable growth model, mainly through viable key transformations (Havrlant & Darandary, 2021). Overall, economic diversification reduces economic vulnerability and ensures sustainable economic growth for the country.

This research draws attention to the complexity of the diversification process and the state of knowledge on economic diversification. This work debates economic diversification based on the definition of diversification of national production as the rebalancing of production with the reallocation of resources between different sectors and, within sectors, between companies, to increase total factor productivity (OCDE & OMC, 2020). We discuss the literature review in the next section.

3. Literature background

To study the impact of economic diversification and digitalization on economic growth, it's important to outline that there are two groups of studies. One focuses on the impact of economic diversification on economic growth, and the other investigates the role of digitalization in the economy. In this research, we present first the studies that analyze the relationship between economic diversification and economic growth, then discuss the link between digitalization and economic growth, and finally the connection between the two groups of research that will be conducted.

Several studies investigated the impact of economic diversification on economic growth (e.g., Smith & Gibson, 1988; Alghamedi, 2014; Albassam, 2015; Gozgor & Can, 2016; Euchi et al., 2018; Banafea & Ibnrubbian, 2018; Aker & Aghaei, 2019; Guendouz & Ouassaf, 2020; Houfi, 2021; Ozdeser et al., 2021).

Smith and Gibson (1988) analyze the impact of industrial diversification on economic stability in nonmetropolitan countries. They conclude that unemployment is more cyclically stable in a more diverse economy than in a less diverse economy. Guendouz and Ouassaf (2020) indicated that diversity in the economy plays a significant role in sustainable economies by creating wealth and jobs and helping to ensure a stable political climate. Ozdeser et al. (2021) using annual data from 1986 to 2018 for the Nigerian economy conclude that

agriculture, tourism, the service sector, remittances, and official development assistance can contribute to economic diversification in the long run. Regarding Saudi Arabia, the results of studies on the diversification of the Saudi economy are somewhat mixed. Some studies proved that there is no real diversification in KSA. Others confirm that diversification has been limited in recent years. Overall, given that Saudi Arabia is one of the main energetic countries and its economy is based on the oil sector, economic diversification was a necessity. KSA began economic diversification in 1970 and further consolidated it in April 2016 with the Saudi Vision 2030 (Al Naimi, 2022). Albassam (2015) indicated that there will be no success in economic diversification for KSA until development plan number nine. It should be noted that many obstacles were found to realize economic diversification. The high entrance barriers for new businesses and the government bureaucracy are among the main factors contributing to a lack of economic diversification and therefore the high rate of unemployment in KSA (Alghamedi, 2014).

Banafea and Ibnrubbian (2018) showed that for KSA, among nine development plans, only for the two last development plans (2005–2014) KSA started the economic diversification. Houfi (2021) used the linear and non-linear ARDL methods to study the impact of economic diversification on economic growth. He measured economic diversification by the Herfindahl index. He proves that there was a weakly positive impact of economic diversification on economic growth in KSA between 1990 and 2018. Euchi et al. (2018) have focused on the contribution of some factors to economic growth to determine if the Saudi economy is diversified or not. They used the tourism sector, entrepreneurial activity, education, and natural resources over the period between 1970 and 2014. They conclude that the Saudi economy is not diversified because the contribution of oil to economic growth is still the largest. In this study to check the role of recent reforms in KSA, we further extend the Euchi et al. (2018) study by adding other variables and using a large database to cover the recent years after the 2030 Vision Reforms. We especially introduce the impact of the digitalization variable on the nexus of economic diversification and economic growth. Indeed, many studies Castellacci and Tveito (2018), Danilin (2019), Pradhan et al. (2019), Al-Rubaier et al. (2020), Aleksandrova et al. (2022), etc. have treated the impact of digitalization on macroeconomic variables. These studies prove that there is an economic, social, and environmental impact of digitalization on the economy.

Castellacci and Tveito (2018) indicated that digitalization through research and development (R&D) can stimulate competitiveness and attract foreign investment. The results of the Pradhan et al. (2019) study showed that an increase of 1% in ITC increased the rate of growth of GDP per capita by nearly 0.396% for the European Union countries. Other researchers (Habibi & Zabardast, 2020; Bahrini & Qaffas, 2019; OECD, 2011) for the Economic Cooperation and Development, the Middle East, North Africa, and Sub-Saharan Africa countries which proved the same findings.

Danilin (2019) stressed that the supremacy of the US and Chinese economies is mainly due to the development of digitalization. This can be explained in part by promotion of exports, the labor force, and foreign exchange, specifically in China, in recent years (Aleksandrova et al., 2022). In addition, for WEF (2023), the process of digitalization in KSA was accelerated by the pandemic of COVID-19. Indeed, throughout the pandemic period (during the years 2020–2021), the KSA authority was obliged to operate all sectors of the economy

(working in industry, commerce, learning, etc.) using technologies. This induced the KSA state to spend more on digital infrastructure and then encourage public-private partnerships to promote the digital economy. According to the World Economic Forum [WEF] (2023), since 2021, KSA become a top digital country among the Gulf Cooperation Council (GCC) countries. This position of the KSA is manifested by an increasingly diversified economy. This means that digitalization can play a significant role in economic diversification. In general, many factors can support economic diversification. A literature review identified those factors, such as governance in countries, the process of privatization, public-private partnership programs, investment in human capital, investment in research and development (R&D), and education reforms. Another important factor that plays a significant role in promoting economic diversification is digitalization. Today, all countries try to invest more in information and communication technologies (ICT) and human capital. This development in digitalization eliminates barriers of geographical distance and creates a knowledge-based economy. Everybody in any place in the world can buy any good or service through digital trade (e-commerce) in the digital economy. So the digital economy facilitates goods and service distribution around the world and then encourages companies to diversify their production. It can reduce costs for companies. For Goldfarb and Tucker (2019), the digital economy can reduce all economic costs, such as study costs, marginal costs, connection costs, etc. Also, Al-Roubaier et al. (2020) indicated that digitalization must support economic diversification and reduce the country's vulnerability to external shocks.

Dong and Xu (2022) showed that digitalization improved the level of exports and promoted the diversification of exports in China. Moreover, digitalization can eliminate corruption and attract new customers (Jurayevich & Bulturbayevich, 2020).

To benefit from these advantages (reduce economic costs and instability) of digitalization, countries must make a supplementary effort to fill the gap in ICT development and be integrated into the digital economy. Shediac et al. (2008) have studied the relationship between economic diversification and sustainable growth for many countries, including GCC countries, G7 countries, and countries with a transformation economy. They showed that to reduce dependency and promote economic diversity, governments must use technologies in industries and invest abroad, as in the case of Norway's economy.

So, the impact of digitalization on economic diversification is acknowledged by many studies. The Intergovernmental Committee of Experts (ICE), in their report in 2019, stated that the digital process is a key pillar of economic diversification (United Nations Economic Commission for Africa, 2019). Also, the digital economy can accelerate economic diversification (Al-Roubaier et al., 2020). However, it is necessary to report that digitalization can make banks more vulnerable and fragile to external shocks (Khattak et al., 2023).

On the other hand, economic diversification can support digitalization. Guendouz and Ouassaf (2020) indicated that economic diversification encourages the development of new knowledge, technology, and digitalization. So, there is a bidirectional impact between economic diversification and digitalization. As noted by Al-Roubaier et al. (2020), the new economic system supported by digital technologies changes the world by influencing market demand and supply and providing opportunities for all countries to participate in the global economy. This participation by countries, including developing countries, encourages and accelerates the digitalization process.

4. Data, variables and econometric study

The objective of this part of the work is to investigate the possible correlations, cointegrations, and causal relationships between economic growth, diversification, and digitalization in Saudi Arabia for the period 1990–2021. We first define the data and method of calculating the principal variables used in this study, then analyze the results of the implemented tests and estimates, seeking different cointegration and causal relationships.

4.1. Data

We combine macro data from several sources. Most importantly, we use time series data for four sectors of the Saudi economy to calculate a diversification index (HHI). To investigate the impact of economic diversification and digitalization on economic growth, we use six variables: (1) economic growth (GDP), (2) non-oil economic growth (NOGDP), (3) economic diversification (HHI), (4) digitalization (DESI), (5) labor force (L), and (6) capital (K), represented by the gross fixed capital formation. Then to analyze and investigate the data and the measurement of the leading indicators, replace the diversification and digitalization levels, respectively. Then we outline the appropriate methodology for the economic diversification index and the digital transformation measured by the digital economy and society information index. The act was issued by the Digital Government Authority on March 9, 2021. The digital transformation of the Saudi government aims to provide all government services and make them easily accessible.

4.2. Variables: definition and measurements

4.2.1. Digitalisation index (DESI)

This part of the paper describes how the digitalization index was expressed and calculated. However, referring to the study of Olczyk and Kuc-Czarnecka (2022), we used the Digital Economy and Society Index (DESI) as a suitable variable that characterizes the development level of the digital economy. Olczyk and Kuc-Czarnecka (2022) verify that DESI sub-indicators can be used to analyze the country's digital transformation. They verified that the original and optimized DESI both satisfactorily explain economic growth as expressed in GDP per capita in European Union countries. Accordingly, at the first level, there are four principal dimensions for DESI, such as human capital, connectivity, integration of digital technology, and digital public services. The second level has 10 sub-dimension indicators. The complete structure of DESI with the weighting system is presented in Table 1.

$$DESI = \sum_{i=1}^{p} \sum_{j=1}^{n} v_i w_j x_{ij}, \quad (1)$$

where, x, is the sub-dimension indicator of digitalization, v_i, is the basic dimension white; w_j, is the Sub-dimension white; i, is the number of basic dimensions, and j, is the number of sub-dimensions. The Table 1 below presents the different compounds of DESI.

Table 1. Dimension of DESI variables (source: authors calculation, based on European Commission, 2017)

DESI Basic dimension	▪ Sub-dimension	Accessibility
2) Human capital (25%)	▪ Internet user skills (50%)	✓
	▪ Advanced skills and development (50%)	✓
3) Connectivity (25%)	▪ Fixed broadband take-up (25%)	na
	▪ Fixed broadband coverage (25%)	✓
	▪ Mobile broadband (40%)	✓
	▪ Broadband prices (10%)	na
4) Integration of digital technology (25%)	▪ Digital intensity (15%)	✓
	▪ Digital technologies for businesses (70%)	✓
	▪ e-Commerce (15%)	na
5) Digital public services (25%)	▪ e-Government (100%)	✓

Note: (✓) – accessible data; (na) – no available data for Saudi Arabia.

4.2.2. Diversification Indicator (HHI):

Used as a proxy, economic diversification is taken as a Value added/GDP: Share of a given main sector in total GDP:

- Agriculture, forestry, and fishing, value added (% of GDP);
- Industry (including construction), value added (% of GDP);
- Services, value added (% of GDP);
- Manufacturing, value added (% of GDP).

We follow the Herfindahl–Hirschman export market diversification index (World Bank, 2013, p. 26). Specifically, we adopt and calculate the Herfindahl–Hirschman to the economic diversification index, as such:

$$HHI_t = \sqrt{\sum_{i=1}^{n}\left(\frac{x_{it}}{X_t}\right)^2}, \tag{2}$$

where: N is the number of sectors considered, x_{it} is the value added of the sector, I, in period t. And Xi is the total value added of the sectors in every period t: $X_t = \sum_{1}^{k} x_{it}$. The higher the HHI, the more the added values are concentrated in a small number of economic sectors. n is the number of considered sectors.

As Algowear Almestneer (2018), The Normalized Herfindahl-Hirschman index is calculated as the following formula:

$$NHHI_t = \frac{\sqrt{\sum_{i=1}^{n}\left(\frac{x_{it}}{X_t}\right)^2} - \sqrt{\frac{1}{n}}}{1-\sqrt{\frac{1}{n}}}. \tag{3}$$

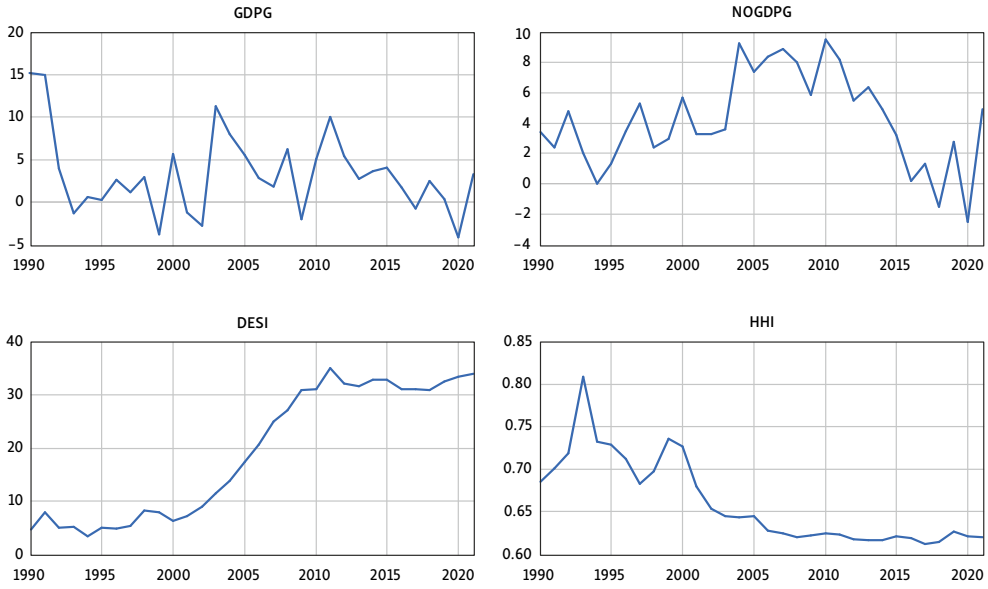
Our economic diversification index can therefore determine whether or not the diversity of the value added to the GDP by various economic sectors has increased.

4.2.3. Descriptive analyses of variable fluctuations

According to Figure 3, although the non-oil GDP index showed some stability and less pronounced oscillations, the Saudi economy's GDP growth rate index saw considerable volatility. This may be explained by the substantial impact that the oil industry had on the GDP of the Kingdom of Saudi Arabia before it entered the stage of economic reform when oil prices saw frequent swings, notably in the last two decades (Kingdom of Saudi Arabia, 2020).

The curve of the digital economy and society index (DESI) and the economic concentration index (HHI) which were used to measure the indicators of digitization and economic diversification, respectively, produced significant findings for the economic situation in the Kingdom of Saudi Arabia.

The Kingdom of Saudi Arabia has distinguished itself in its pursuit of the digital economy, and its efforts and initiatives within the framework of its economic policies included in the Kingdom's Vision 2030, which aims to diversify the economy and expand the production base, have led to a decrease in economic concentration in favor of expansion and diversification. This is reflected in the rapid growth of the digitization index (DESI), in contrast to the significant decrease in the economic concentration index (HHI).



Note: GDPG is the Economic growth rate. NOGDPG is the non-oil economic growth rate. DESI is the digital economy and society index and HHI is the economic concentration index.

Figure 3. Graphical evolution of GDPG, NOGDPG, DESI, and HHI of KSA (1990–2021) (source: authors' calculation and elaborations)

4.3. Econometric study and analysis

To investigate empirically the role of digitalization and diversification in the Saudi economy we follow the next steps: first, we verify the characteristics of variables by Unit root tests. In this study, we use the Augmented Ducky Fuller (ADF) and KPSS tests. Second, we determine the direction of causality between variables by using the causality tests of Toda-Yamamoto (Toda & Yamamoto, 1995). Third, we study the possibility of the existence of the long-run relationship between variables by employing the bounds test. Finally, we estimate short and long-run coefficients in the model. According to the International Monetary Fund's (2021) report, Saudi Arabia is the world's largest producer and exporter of oil and will account for nearly 70% of the country's total exports in 2020 and 53% of the government's revenues. In addition, there is a continuous growth of the private sector in the KSA economy the non-oil sector mainly. This information helps to study the implications of digitalization and diversification on the global economy by assessing their impacts on GDP growth and the private sector by taking non-oil GDP as an endogenous variable. Then, we adopt the methodology, which takes two models to explain the separate effects, as follows:

$$\textbf{Model 1: } GDPg_t = f\left(DESI_t, HHI_t, L_t, K_t\right); \tag{4}$$

$$\textbf{Model 2: } NOGDPg_t = f\left(DESI_t, HHI_t, L_t, K_t\right). \tag{5}$$

To improve these relationships between diversification and digitalization and their effects on the production base in the Saudi Arabian economy, we analyze the dynamics of econometric relations as shown in Figure 4. Specifically, we propose that digitalization and diversification can have a positive impact on economic growth, especially in the non-oil sector. Furthermore, we expect the contributions of the specific dimensions of diversification to economic growth performance. The conceptual model can be established as follows:

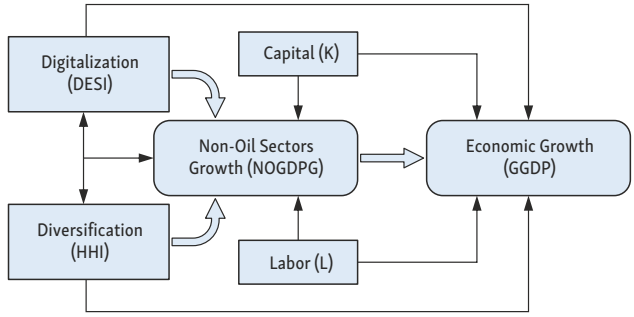


Figure 4. Conceptual model (source: authors' elaboration)

4.3.1. Unit root test results and lag Order Selection

The results of all variables' stationarity are presented in Table 2 below.

Looking at Table 2, we can conclude that some variables are integrated with order zero, others are integrated with order one, and no variable is integrated with order two. As the ADF and KPSS test results indicate, the GDPG variable is stationary at the level, and all other

variables are stationary at the first difference. For the (L) and (NOGDP) variables, because of the contradiction of results between the ADF and KAPSS tests, we have employed the Phillips-Perron (PP) test. The results of the PP tests confirm that the L and NOGDP variables are integrated with order one.

Flowing from the lag length criteria used in econometric work, the optimal orders of the ARDL model are lag 3 for model 1 and lag 4 for model 2[1].

Table 2. Unit root tests (ADF and KPSS) (source: authors' estimations)

Variables	Constant (i)		Constant and trend (ii)		Order of Integration
	ADF				
	Level	First difference	Level	First Difference	
GDP	–4.567*	–4.401*	–4.408*	–6.194*	I(0)
NOGDP	–1,501	–8,438*	–1,452	–8,353*	I(1)
HHI	–1.381	–6.183*	–0.602	–6.140*	I(1)
DESI	–0.414	–4.617*	–1.259	–4.553*	I(1)
K	–1.887	–6.008*	–2.610	–5.900*	I(1)
L	–0.151	–3.334*	1.251	–5.300*	I(1)
KPSS					
GDP	0.220*	0.105*	0.096*	0.058*	I(0)
NOGDP	0,153*	0,129*	0,153*	0,129*	I(0)
HHI	0.616	0.140*	0.147	0.137*	I(1)
DESI	0.581	0.135*	0.098*	0.135*	I(1)
K	0.523	0.280*	0.100*	0.277	I(1)
L	0.403*	0.662	0.198	0.367	I(0)
Critical levels KPSS					
1%	0.73		0.21		
5%	0.46		0.14		
10%	0.34		0.11		

Note: *, **: significantly at levels of 5% and 10%.

4.3.2. Results of causality tests

a – Toda-Yamamoto's (1995) causality tests

To assess the causal relationship between the variables under consideration, we applied the Toda Yamamoto causality test, which is based on the block homogeneity Wald test technique. Table 3 summarizes the findings.

The results, reported in Table 3, indicate that there is only unidirectional causality respectively from economic growth (GDP), non-oil economic growth (NOGDP), and economic diversification (HHI) to digitalization (DESI) and from non-oil economic growth and diversification to gross fixed capital formation (GFCF). This result agrees with that of Guendouz and

[1] The results of the Optimal Lag selection criterion for model 1 and Model 2 are available upon request.

Table 3. Results of variables causality of Toda-Yamamoto (1995) (source: authors' estimations)

Dependent variable	Excluded variables						Block Exogeneity All variables together
	GDPG	*NOGDPG*	*HHI*	*DESI*	*L*	*K*	
GDPG	–	0.91 (0.91)	0.21 (0.89)	0.39 (0.82)	1.22 (0.54)	0.33 (0.84)	2.51 (0.99)
NOGDPG	0.95 (0.62)	–	1.00 (0.60)	2.17 (0.33)	1.45 (0.48)	0.69 (0.70)	11.63 (0.31)
HHI	0.23 (0.88)	0.16 (0.91)	–	0.28 (0.86)	0.95 (0.62)	0.18 (0.91)	1.40 (0.99)
DESI	6.21 (0.04)*	7.73 (0.02)*	20.26 (0.00)*	–	1.96 (0.37)	0.46 (0.79)	34.24 (0.0002)*
L	0.1 (0.95)	2.73 (0.25)	1.68 (0.43)	3.01 (0.22)	–	0.02 (0.98)	9.58 (0.47)
K	0.90 (0.63)	9.18 (0.01)*	7.28 (0.02)*	4.17 (0.12)	0.76 (0.68)	–	18.23 (0.05)*

Note: *, **: significativity at the levels of 5% and 10%. The values in each box represent chi-square (Wald) statistics for the joint significance of each other lagged endogenous variables in that equation. The last column's statistics are the chi-square statistics for the joint significance of all other lagged endogenous variables in the equation.

Ouassaf (2020) in their study, which confirms that diversification develops the economy of new knowledge (the digital economy).

b – Pairwise Granger Causality Tests

Table 3 shows Toda-Yamamoto's (1995) causality tests, which indicate that there is only unidirectional causality from economic diversification (HHI) to digitalization (DESI). This result was confirmed by Pairwise Granger Causality Tests (Dumitrescu & Hurlin, 2012) which take into consideration the dabble direction of causality. in Table 4, Pairwise Granger Causality Tests prove indirect causality from diversification to non-oil economic growth through digitalization.

Table 3 shows Toda Yamamoto's (1995) causality tests, which indicate that there is only unidirectional causality from economic diversification (HHI) to digitalization (DESI). This result was confirmed by pairwise Granger causality tests (Dumitrescu & Hurlin, 2012), which take into consideration the dabble direction of causality. In Table 4, pairwise Granger causality tests prove indirect causality from diversification to non-oil economic growth through digitalization.

Table 4. Pairwise Granger Causality Tests (source: authors' estimations)

Null Hypothesis:	Obs	F-Statistic	Prob.	Causality direction
NHHI does not Granger Cause DESI	29	5.2392***	0.0070	NHHI → DESI
NHHI does not Granger Cause GFCF	29	4.6402***	0.0116	NHHI → GFCF
NHHI does not Granger Cause L	29	3.5582**	0.0308	NHHI → L
DESI does not Granger Cause NOGDPG	29	3.5424**	0.0313	DESI → NOGDPG

Note: (***) and (**) are significant at 1% and 5% respectively and main that you should reject the null hypothesis.

Overall, according to the results of the Unit Root Test and Causality Tests, the suitable model to estimate equations (1) and (2) is autoregressive distributed lag (ARDL). It is used to find out the long-run and short-run causal relationship among the variables.

To determine whether diversification and digitalization have a long-run equilibrium relationship, we applied the bounds testing approach to cointegration, and error correction models developed within an autoregressive distributed lag (ARDL) framework, for the period 1990 to 2021.

5. The ARDL model: specification, estimation and results analysis

5.1. The ARDL model specification

The unrestricted ARDL specification of the long-run relationship between growth rate in the global economy and non-oil sector growth (GDPGt and NOGDPGt), diversification, and digitalization in the KSA is expressed as follows:

Model 1:

$$\Delta GDPG_t = \alpha_0 + \alpha_1 T + \beta_1 DESI_{t-i} + \beta_2 HHI_{t-i} + \beta_3 L_{t-i} + \beta_3 K_{t-i} + \sum_{i=1}^{n-1} \gamma_1 \Delta DESI_{t-i} + \sum_{i=1}^{n-1} \gamma_2 \Delta HHI_{t-i} + \sum_{i=1}^{n-1} \gamma_3 \Delta L_{t-i} + \sum_{i=1}^{n-1} \gamma_4 \Delta K_{t-i} + \varepsilon_t. \quad (6)$$

Model 2:

$$\Delta NOGDPG_t = \delta_0 + \delta_1 T + \theta_1 DESI_{t-i} + \theta_2 HHI_{t-i} + \theta_3 L_{t-i} + \theta_3 K_{t-i} + \sum_{i=1}^{n-1} \varphi_1 \Delta DESI_{t-i} + \sum_{i=1}^{n-1} \varphi_2 \Delta HHI_{t-i} + \sum_{i=1}^{n-1} \varphi_3 \Delta L_{t-i} + \sum_{i=1}^{n-1} \varphi_4 \Delta K_{t-i} + \mu_t. \quad (7)$$

where *GDPG* and *NOGDPG* are the dependent variables and represent gross domestic product and non-oil gross domestic product, respectively. These variables are explained by exogenous variables (*DESI*, *HHI*, *L*, and *K*) in their long-run and short-run relationships. (β_i and θ_i) represent a long-run parameter, while (γ_i and φ_i) are the short-run parameters. *T* is the time trend and (ε and μ) refers to random error.

Cointegration and Bounds tests

Since there is a difference between variables in order of integration, we can use bounds tests (Table 5) to verify the existence of a long-run relationship between variables.

The results above indicate that there is a cointegration relationship between variables. We can estimate the models now in the next step.

Table 5. Cointegration and Bounds tests (source: authors' estimations)

Model 1 (*GDP Dependent variable*)	Statistical Value	Significant Level	Lower Bound	Upper Bound	Decision
F-statistic	8.3507	10%	2.81	2.93	Cointegration
		5%	2.14	3.34	
		1%	2.82	4.21	
t-statistic	–8.8284	10%	–1.62	–3.49	Cointegration
		5%	–1.95	–3.83	
		1%	–2.58	–4.44	
Model 2 (*NOGDP Dependent variable*)	Statistical Value	Significant Level	Lower Bound	Upper Bound	Decision
F-statistic	6.7390	10%	1.9	3.01	Cointegration
		5%	2.26	3.48	
		1%	3.07	4.44	
t-statistic	–6.9764	10%	1.9	3.01	Cointegration
		5%	2.26	3.48	
		1%	3.07	4.44	

Notes: F-Bounds Test, Null Hypothesis: No levels relationship & t-Bounds Test, Null Hypothesis: No levels relationship.

5.2. Estimated long run coefficients using the ARDL approach and error correction regression

Table 6. Estimated results of ARDL Optimal Model Lags (1990–2021) (source: authors' estimations)

A: Equation (3) Selected model: ARDL (2,1,3,3,3,2) Dependent Variable: **D(GDPG)**			
Variable	Coefficient	t-Statistic	Prob.
COINTEQ*	**–2.6602*** **	**–10.4393**	**0.0000**
D(GDPG(–1))	1.1392***	6.8984	0.0000
D(NOGDPG)	1.0837***	7.6603	0.0000
D(NHHI)	**11.000**	**1.2265**	**0.2389**
D(NHHI(–1))	3.6175	0.4078	0.6892
D(NHHI(–2))	–52.1366***	–5.8247	0.0000
D(DESI)	**–1.6431*** **	**–5.1321**	**0.0001**
D(DESI(–1))	–1.2465***	–4.5708	0.0004
D(DESI(–2))	–0.4435**	–2.0289	0.0606
D(L)	7.2749***	9.6395	0.0000
D(L(–1))	0.3091	0.4135	0.6850
D(L(–2))	10.7842***	8.8878	0.0000
D(GFCF)	2.6956***	7.1784	0.0000
D(GFCF(–1))	–2.0266***	–6.4509	0.0000
R-squared 0.9280		Adjusted R-squared	0.8656
F-statistic (Prob) 14.8803 (0.0000)		Durbin-Watson stat	2.2193

Note: * p-values are incompatible with the t-Bounds distribution.

End of Table 6

B: Equation (3) Dependent Variable: **D(NOGDPG)** Selected model: ARDL(4, 4, 4, 3, 0)			
Variables	Coefficient	t-Statistic	Prob.
COINTEQ*	**–0.4071*** **	**–6.9764**	**0.0000**
D(NOGDPG(–1))	–1.1243***	–7.5016	0.0000
D(NOGDPG(–2))	–0.8645***	–4.5427	0.0006
D(NOGDPG(–3))	–1.0499***	–5.9818	0.0000
D(NHHI)	**16.878**	**2.0739**	**0.0585**
D(NHHI(–1))	–34.400***	–4.0089	0.0015
D(NHHI(–2))	–35.166***	–4.7541	0.0004
D(NHHI(–3))	–23.210***	–3.3836	0.0049
D(DESI)	**0.4945**	**2.4400**	**0.0298**
D(DESI(–1))	–0.2538	–1.2420	0.2361
D(DESI(–2))	**0.7626*** **	**3.8799**	**0.0019**
D(DESI(–3))	**0.4608** **	**2.3108**	**0.0379**
D(L)	**2.2954*** **	**4.1910**	**0.0011**
D(L(–1))	0.8942	1.7147	0.1101
D(L(–2))	3.7885***	5.0758	0.0002
R-squared F-statistic (Prob)	0.8862 7.233(0.0005)	Adjusted R-squared Durbin-Watson stat	0.7637 2.1531

Note: * p-values are incompatible with the t-Bounds distribution.

Table 6 presents the estimated results after a long process of appropriation tests to select the suitable method of estimation. According to the results, the same interpretations were identified:

- As the results show, the cointegrating relationship is stable because the coefficient of the lagged error correction term is negative and significant.
- The ECM measures the speed of adjustment of the endogenous variable in the case of a shock to equilibrium. In this study, the ECM estimation suggested that short-run deviations in GDP growth were corrected in about 6 months in the first model, and in the second model, the ECM estimation suggested that short-run deviations in GDP growth were corrected by 40.7% every year toward the long equilibrium.
- The results of diagnostic and stability tests indicate that the ARDL model is well fitted, as proved by the values of R2 (0.928) and (0.886) and adjusted R2 (0.865) and (0.764), respectively, in models 1 and 2. The values of the Durbin-Watson test statistics are (2.219) and (2.15), which implies that spurious regression does not exist in the model.
- The results of ECM above show that both digitalization (DESI) and economic diversification (HHI) are statistically significant and have a positive impact on non-oil gross domestic product (NOGDPG) in the short run. Their coefficients and probabilities are,

respectively, 16.878 (0.585) and 0.4945 (0.0298). The results also show that in the long run, after two or three years, digitalization (DESI) positively contributes to NOGDPG, as indicated by the P-value of the coefficients DESI(–2) = 0.0019 and DESI(–3) = 0.0011.

- When considering gross domestic product (GDPG) as a dependent variable, the results prove that there is no impact of economic diversification (HHI) on GDPG and that digitalization (DESI) negatively hits economic growth in the short run (–1.643085 (0.0001)). This negative impact of digitalization becomes increasingly weak in the long term (DESI(–1) = –1.246 (0.0004) and DESI(–2) = –0.443 (0.06)).

Overall, the results of model 2 (NOGDPG is a dependent variable) are more significant than those of model 1 (GDPG is a dependent variable). This can be explained by the fact that despite this progress in economic diversification in Saudi Arabia, the Saudi economy was still dominated by the oil sector during the period of study. But this oil supremacy in the economy becomes increasingly weak over time.

5.3. Diagnostic and stability tests of the estimate models

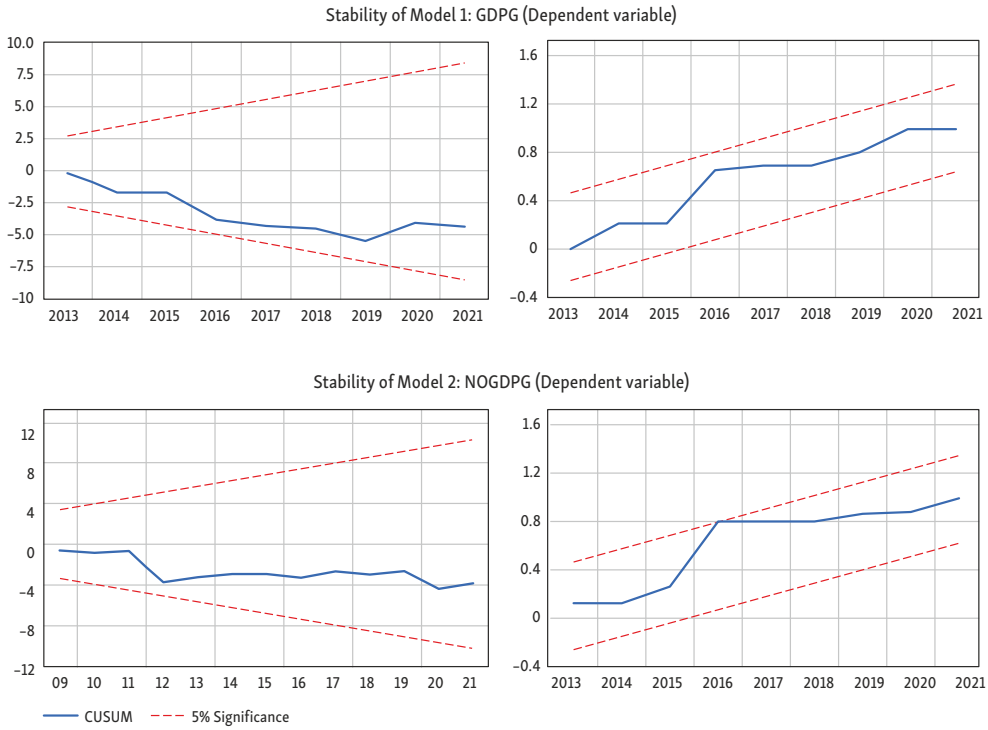
Diagnostic tests, the Breusch-Godfrey serial correlation LM test, and the Breusch-Pagan-Godfrey test for heteroscedasticity (no autocorrelation, heteroscedasticity, and nonnormality, see Table 7) confirmed the stability of models.

Table 7. ARDL diagnostic tests (source: authors' estimations)

Tests	Model1	Model2	Test results
	Value (probability)	Value (probability)	
Breusch-Godfrey serial correlation LM test for Autocorrelation	0.8409 (0.4849)	1.0147 (0.4204)	No serial correlation
Breusch-Pagan-Godfrey for Heteroscedasticity	0.8017 (0.5348)	1.6129 (0.1998)	Homoskedasticity
Jarque-Bera Test for Normality	1.2781 (05277)	1.0997 (0.5770)	Normal distribution
Ramsey RESET Test for Specification	1.1588 (0.2916)	3.4234 0.0757	Functional form

According to the diagnostic statistics in Table 7, all the ARDL models indicate no evidence of those estimation problems of serial correlation, inappropriate functional form, non-normality, and heteroscedasticity. Hence, we consider that the empirical findings of this study are plausible to draw policy implications for the diversification hypothesis in Saudi Arabia.

Figure 5 shows both the graphical representations of the cumulative sum (CUSUM) and the cumulative sum squared CUSUMSQ statistics of recursive residuals, verifying the stability of the ARDL model. The figures above indicate that statistically, the estimate model remains stable in the short-run and long-run.



Notes: Plot of cumulative sum and cumulative sum of squared recursive residuals. Null hypothesis: parameters are stable.

Figure 5. Stability tests: (CUSUM) and (CUSUM Squares) (source: authors' elaboration)

5.4. Empirical results and analysis

There is no doubt that the digital transformations, which included the various economic sectors: industrial, investment, commercial, and service, have increased economic diversification and the base of production. This makes us say that, the digital economy helps in promoting economic diversification, as proved in the literature reviewed by (e.g., Al-Roubaier et al., 2020; Jurayevich & Bulturbayevich, 2020). Also, from the above results of two estimated models, 1 and 2, based on the technique of Toda-Yamamoto (1995) tests and pairwise causality of Dumitrescu and Hurlin (2012), we conclude that the digital economy is supported by economic diversification. Because there is a causal relationship between the economic diversification index (HHI) and the digitalization index (DESI). Furthermore, our findings suggest a long-term association between economic growth, economic diversification, and digitization. When we study the Saudi economy without the oil sector (model 2) rather than the global economy (model 1), we see a long-run positive influence of digitalization and diversification on economic growth. These findings appear to be more widely accepted since, while the Saudi economy has diversified significantly, the oil industry continues to dominate the economy through 2021 (the end of the studied period). On the other hand, the findings of our study stipulate that in the global Saudi economy (model 1), digitalization (DESI) has a negative im-

pact on economic growth at the beginning (the short run), but over time the negative impact weakens and becomes positive after a long enough time. The results of the heteroscedasticity and normality tests show that the model is not unstable.

6. Conclusions and policy implications

In this paper, we have investigated and examined the role of economic diversification strategies and digitalization in the global economy and the role of the digital economy in sustainable growth. Empirically tested trends in economic growth for Arabia's economy through the Autoregressive Distributed Lag Model (ARDL) Approach from 1990 to 2021 have been used. To identify the net impact of economic diversification and digitalization on the Saudi economy, we have employed two models. The first model (model 1) investigates the relationship between global economic growth (GDP), economic diversification, and the digital economy. The second model (model 2) focuses on the relationship between non-oil economic growth (NOGDPG), economic diversification, and the digital economy. The findings offer compelling evidence that economic diversification and digitization both directly affect economic growth as well as indirectly through their effects on non-oil GDP growth.

The results of the causality tests confirmed the existence of causality between variables in the two models. The causality runs from economic diversification to digitalization. Also, there is causality from economic diversification to capital (K) and from non-oil economic growth (NOGDPG) to digitalization (DESI) and capital. This is proven by economic literature. Indeed, the digital economy infrastructure requires funds to purchase tools, software, and necessary skills (human capital, training, etc.). These results have some important implications for anti-corruption policy. Given that the non-oil income will be used to promote digitalization, this development of digitalization can reduce corruption in the oil sector[2]. The benefit of a decline in corruption in the oil sector can encourage economic diversification in the country.

The output of bound tests has shown that there is a long-run dynamic between economic growth, economic diversification, and digitalization. In the short run, the results indicated that digitalization and economic diversification made a positive contribution to non-oil gross domestic product. This can enhance global economic growth.

The estimation of the error correction model provides evidence that, in the long run, digitalization contributes to the progress of non-oil economic growth and therefore to the sustainable economic growth of Saudi Arabia. This development of non-oil income decreases the supremacy of the oil sector in the economy and creates economic diversification. In the long run, the results also show that there is no direct impact of economic diversification (HHI) on economic growth (GDPG). But this impact is transmitted through non-oil economic growth. Moreover, our findings indicate that digitalization (DESI) has a negative impact on economic growth in the short run due to the strong revenues spent in the digital economy, the inadequacy of technology utilization by producers (workers) and consumers, and other problems of digitalization (scams, theft, electronic blackmail, etc.). This negative impact begins to disappear over time.

[2] The results of the Optimal Lag selection criterion for model 1.

Overall, we conclude that even though the Saudi economy is still dominated by the oil sector, the impact of the 2030 Saudi Vision started in 2016 to digitalize and diversify their economy is well established. This is well shown, especially in the impact on non-oil sectors (NOGDPG) in our study. These results have some implications for the KSA authority. First, the responsibility of KSA is to strengthen all policies that promote digitalization transformation at the regional and global levels. They should encourage the Ministry of Higher Education to learn ICTs engineers or experts to establish the main infrastructure of human capital. Second, KSA must accelerate the energy transition process (from non-renewable energy to renewable energy) to improve the environment quality and then consolidate the economic diversification. Moreover, KSA must develop more rules and laws to attract foreign investment in ICTs.

Despite, that the results of our study are significant, this research has some limitations. Indeed, the sample period for the current study is limited to 1990–2021 due to data availability. The diversification index measure is based only on the major economic sectors. We must ultimately establish a compound index based on a large and significant sub-index and period for future studies to fully explore the economic effects of diversification. Also, we can apply this study to the GCC or MENA countries in order to identify the position of KSA among the countries of their region in the digitalization and economic diversification process.

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Author contributions

The researchers jointly worked on the methodology, software, analysis, investigation, writing, and editing of the research paper. Mohamed NEFFATI conceived the study and the data analysis, and was responsible for the idea and for data collection, and contributed to the empirical analysis, and data interpretation and wrote the first draft of the article. Rafik JBIR contributed to the theoretical background, empirical analysis and writing draft.

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