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Investigating the impact of bridging the digital divide on reducing unemployment and achieving SDGs in Saudi Arabia: Panel ARDL approach

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ABSTRACT

This study seeks to examine how Internet penetration and usage affect the unemployment rate among Saudis by gender. A descriptive analysis was used to generate two standard models and conduct an analysis on them using the ARDL Approach. The findings reveal that there is a statistically significant relationship between the independent variables in the model developed, which are "Internet penetration rate" and "male Internet use," and the dependent variable "male unemployment rate." Additionally, there is a relationship between the independent variables "Internet penetration rate" and "female Internet use" and the dependent variable "female unemployment rate." In addition, the findings indicated that bridging the digital gap will help reduce unemployment and attain the sustainable development goals in the Kingdom of Saudi Arabia. Policymakers should focus on the expansion of Internet coverage, upgrading digital skills, e-employment, enhancement of digital infrastructures for SMEs, and aligning digital inclusion strategies with Vision 2030 and the UN SDGs to reduce the digital divide, tackle unemployment, and contribute to further sustainable economic development. This study adds to the existing literature by taking a closer look at how Internet penetration and usage affect unemployment rates in Saudis by gender and shows that this can reduce unemployment through bridging the digital divide and subsequently support advancing toward the SDGs.

Contribution/ Originality: This study presents a new dimension of gender-based analysis of how internet penetration and its usage affect unemployment rates in Saudi Arabia. A notable feature of this paper is that it links digital inclusion to specific SDGs, thereby highlighting how bridging the digital divide reduces unemployment and promotes inclusive sustainable economic development.

1. INTRODUCTION

"Digital economy" is the term used to describe the range of commercial and economic activities that rely on digital communications and digital technologies. These include digital financial services, digital marketing, digital content, e-commerce, cloud services, software, computer games, and digital production (Xia, Baghaie, & Sajadi, 2024).

With the growth of digital transformation, economies around the world are becoming increasingly dependent on digital infrastructure, resulting in significant socio-economic changes. Nonetheless, the advantages of digitalization are not equally shared, leading to a "digital divide" that has a considerable impact on future employment opportunities, economic inclusion, and social participation (Hilbert, 2020). People and communities without access to digital technologies often face challenges in obtaining jobs, which restricts economic development and exacerbates socio-economic inequality (Van Dijk, 2023).

This digital divide is particularly meaningful in Saudi Arabia, where the government pursues rapid economic diversification plans under Vision 2030, required to achieve job creation, boost female workforce participation, and spur on digital transformation to catalyze sustainable development (Saudi Vision 2030, 2016). While some countries have made substantial investments in their digital infrastructure, challenges remain with respect to Internet penetration, digital skills, and technology uptake that contribute to levels of employment and participation in the labor force, notably among women and youth (Al-Ghamdi & Badawi, 2022). Closing this gap is essential, not only for meeting Sustainable Development Goals (SDGs) such as quality education (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), industry and innovation (SDG 9), and reduced inequalities (SDG 10), but also for enabling economic resilience and social equity.

The focus of this study is driven by the pressing necessity of the relationship linking internet penetration with essential digital skills and the employment rate in the Kingdom of Saudi Arabia. As entire economies shift towards digital, understanding the impact of digital adoption on labor market outcomes is critical for effective policy formulation. As for the existing literature, while some studies have explored the effects of digitalization on employment as a whole, few have investigated this relationship disaggregated by gender in the Saudi labor market. This remains an important gap to address, particularly given Saudi Arabia's national strategies aimed at increasing female labor participation and reducing unemployment rates (Ministry of Economy and Planning, 2023).

In addition, the study will also inform policy debate by analyzing the potential impact of bridging the digital divide on unemployment and sustainable economic growth. With technology becoming increasingly important for modern labor markets, recognizing major determinants of digital inclusion can inform specific interventions to improve Internet accessibility, digital literacy training initiatives, or remote work opportunities. These findings are essential for policymakers, businesses, and educators looking to align digital transformation with employment strategies.

The uniqueness of this research is seen in utilizing the Autoregressive Distributed Lag (ARDL) method to evaluate the long-run and short-run impacts of Internet penetration and utilization on the unemployment rates of the sexes in Saudi Arabia. This is a novel contribution to the literature, as it goes beyond existing studies at the macroeconomic level that study digital transformation only, to analyze how important factors such as gender affect the relationship between technological, structural, and digital inclusion, each of which has a dynamic impact on male and female employment. Channeling digital adoption towards targeted SDGs, this research also emphasizes the impact on wider sustainable development agendas of digital inclusion. In addition, the results of this study have offered evidence-based policy recommendations that could help reach the goals of Vision 2030, especially within the context of an inclusive and technology-driven labor market.

2. LITERATURE REVIEW

2.1. Concept of the Digital Divide

The unequal distribution of access to digital communication networks is called the "digital divide." A common narrative around the digital gap is that it is a social problem that impedes innovation, economic expansion, and social inclusion (Abubakr et al., 2024; Marks, 2015). Using the "digital divide" as a metaphor to explain the relationship between technology and social inequality is inaccurate and inappropriate. However, authorship is not binary; rather, it is a continuum with economic and cultural context. In Egypt, the conventional approach to addressing the digital

gap is to provide equipment and observe people's creative uses of it. Additionally, they can provide equipment to instructors in countries like Chile that are ready to accept it, but they will be aware that doing so prior to supporting new educational technology initiatives may be a pointless endeavor akin to a ponderous dinosaur park. For the same reason, the notion of the digital divide is unable to adequately explain these longer-term social dynamics. If we do not prioritize social mobilization and transformation, the gap will persist (Ahmad, Bin Hidthiir, Rahman, Junoh, & Yusof, 2025; Warschauer, 2003).

Further research on ICT is required, including a more formal measurement of the absolute digital divide, an analysis of the rise in age-related disparities, and a study on collaboration among industrialized nations. As home broadband adopters, smartphone users are also much more likely to use their devices for job searches, a trend that holds true for the majority. Nevertheless, given that smartphone use does not completely eradicate disparities in how people use the internet, home broadband is among the most crucial for practicing digital citizenship (Mossberger, Tolbert, & Hamilton, 2012). This regrettable gap can make those worlds appear so disconnected from one another that they will never be able to enjoy an education, a job, or a high quality of life together again (bin Hidthiir et al., 2024; Colom, 2020).

2.2. Unemployment

As economic growth falters in emerging and developing economies, rising unemployment globally is a serious social problem. This could be addressed by legislation that forbids discrimination and advances gender equality, in addition to gender budgeting (Ahmad, Hidthiir, & Rahman, 2024; International Labour Organization (ILO), 2016). On the other hand, unemployment is a lagging economic indicator, meaning that it rises when GDP slows and vice versa. Policies and conditions in the labor market are major factors that determine the unemployment rate. According to estimates, there is an output gain of roughly one or two percentage points for every one percent decrease in the unemployment rate (from, say, nine to eight percent). At best, the natural unemployment rate is the result of a clear reconciliation between structural and frictional rates. Being unemployed means not applying for jobs. The hidden unemployment statistics also include discouraged workers and part-timers seeking full-time positions. The features and policies of the labor market impact the natural rate of unemployment (Oner, 2020).

2.3. Frictional Unemployment

Frictional unemployment, which occurs when someone quits their job and obtains a new one, is a fundamental component of a functioning economy, which explains why there are still so many unemployed people. This kind of unemployment is rather common in a dynamic economy where people are constantly searching for better work. The most recent data on employment rates in various nations is available in the World Employment and Social Outlook: Trends 2016, which indicates that trends linked to economic growth have failed since concerns about social unrest have outweighed high unemployment rates. In order to eliminate frictional unemployment, sustainability necessitates addressing job quantity, quality, and labor force growth over time. Furthermore, incorporating the gender dimension into youth employment through clear policy design may help bridge the employment gap and enhance the quality of jobs overall (Change, 2022).

Frictional unemployment—the natural, long-run form of joblessness—remains unchanged regardless of whether the economy's demand for labor falls or rises. We expect digital technology (such as online job search and ad services, etc.) to effectively reduce the time and money spent searching for and matching employers with employees, which would decrease frictional unemployment. Given the inverse relationship between national unemployment levels and the extent to which a digital economy is present, as measured by the percentage of adults paying bills online, emerging economies may benefit more from this linkage (Lederman & Zouaidi, 2022).

2.4. SDGs

The Sustainable Development Goals (SDGs) were developed by the UN General Assembly to address numerous social, economic, and environmental problems that exist globally in order to realize sustainable development on a global scale. ICTs serve as an enabler in the World Summit on the Information Society (WSIS), which has established several action lines that contribute to the SDGs' accomplishments. The WSIS Stocktaking Platform is a freely available database of programs, projects, and best practices that employ ICTs to enhance people's everyday lives globally, particularly in attaining the SDGs. Specifically, the emphasis is on the connections between the SDGs and WSIS Action Lines to improve ICTs for sustainable development (International Telecommunications Union, 2014).

The 2023 Special Edition states that transforming for global goals encompasses some of the necessary actions if we are serious about achieving our goals by 2030. While there has been significant progress toward a limited number of the targets, addressing urgent problems like hunger, poverty, and climate change remains insufficient. The COVID-19 pandemic has had a significant and enduring impact, but it is only one example of many global crises that exacerbate already-existing inequality. The burden of bridging financial gaps and bearing substantial debt loads disproportionately affects developing nations. We need to take swift, coordinated action, incorporating new SDGs. In order to rebuild better together, incentives must increase financing and address structural shocks and inequalities (United Nations, 2023).

It is a significant policy document since it lays out the shared objectives for tackling global issues, such as promoting social and economic development. The document establishes a consistent policy framework for sustainable development. The synergy of the SDGs is key. Since the SDGs are mutually inclusive and supra-partner, no objective supersedes any other. Put differently, the pursuit of one goal should not obstruct the pursuit of other objectives. In fact, this presents a significant challenge as well, and in accordance with the objectives (ODS) criteria, these cover a very wide range of ODS outside of themselves that fall under the purview of the policies. Every country's reality is different from this impractical goal set by the SDGs, as there is no room for flexibility in a one-size-fits-all strategy. For developing or least-developed countries, solutions that are workable in developed countries may not be the best ones. We must consider the unique qualities and needs of each country to ensure the sustainability of the SDGs (Singh, Singh, Alam, & Agrawal, 2022). This study is an endogenous contribution to understanding the impact of bridging the digital divide on reducing unemployment and achieving SDGs (4.4, 4.5, 5.b, 8.5, 8.6, 9.2, 9.c, 16.7, 17.6, 17.8) in Saudi Arabia.

2.5. Inequity

A significant issue for women is the lack of equal opportunities regarding career advancement. Patriarchy and family dynamics have considerable links to the progression of women's careers. We know of no relationship between gender stereotypes and independent attributes. Accordingly, the research contributes to the feminist thought process with a more thorough understanding of employers' career prospects and provides information for businesses and the government on factors affecting it. A study about an important aspect of preparing for a career in Malaysia revealed the risks women take to enhance their job advancement, replacing previous feminist and glass ceiling ideas. The study also investigates some foreign concepts associated with advancement at work, such as employment and cultural capital, for a more comprehensive understanding of professional success as it relates specifically to females who may have advanced professionally in developing countries (Bin Hidthir, Khan, Junoh, Yusof, & Ahmad, 2025; Moorthy et al., 2022).

This is in line with several others stating that there may be competitive party systems outside Europe or the West that have similarly seen emerging patterns toward a gender divide. Certainly, not the least of which includes potentially changing popular conceptions that women are more conservative and stronger than men (Inglehart & Norris, 2000).

In ICT employment, women continue to struggle with the following (not addressing experts who recommend digital solutions for 5G job-friendliness like Ground Control to minimize inequality risk): Women and the positive locks under the belief in human superiority over robots, some digital knowledge, and actual authorities offering a helping hand all cry out for regulatory intervention. Closing the digital divide will encourage inclusive growth, contribute to certain SDGs, and help boost the economy. The report recommends policies and calls for the implementation of gender equality in digital. We can only achieve this by narrowing the digital gender divide and ensuring that growth is brought about in an inclusive manner (Chandra, 2022; Hidthiir, Ahmad, Junoh, & Yusof, 2024).

2.6. Global Employment Trends for Youth

Rising employment may be part of the equation. As it becomes easier for a larger share of young people to find work, shifts in the percentage living at home could mean that more are working or studying full-time and thus able to afford housing. The 20–24 NEETs are much rarer and, being of slightly more advanced age than the VO cohort (75% have "graduated" its upper boundary), are probably in some non-employment education or training; yet many still will not be due to those stubborn issues that inhibit young people from making it into stable work. Overall, young women aged 15 to 29 are more likely than their male counterparts to be NEETs because they participate less in the labor market. In conclusion, the rate of young unemployment worldwide is expected to peak at 15.6% in 2021 (International Labour Organization, 2022).

The state of youth labor registers alarming signs, as several challenges persist in hindering development. ILO: 268 million people are out of work worldwide, a gap worth noting as the employment rate falls by 12.3%. Women continue to be the worst off, with 15.0% of all employed women now unemployed (compared with just 10.5%, or more than one in ten men) (International Labour Organization, 2023).

Nonfarm payroll employment increased by 216,000 in December 2023; the average monthly gain of jobs over the prior three months was around 225,313. Social services have created, on average, 22 thousand new jobs a month so far this year. We also see limited upside in government employment, as reflected in the 52,000-jump last month that almost halted the long-term downtrend assumption and resulted in a very narrow +56K average monthly job increase for all of this year. The leisure and hospitality sector created 40K positions in December after shedding jobs during the Omicron wave, which adds up to less than a dozen new jobs per month over the course of 2.5 years through early 2023. Employment in the manufacturing sector is flat for a second month (+6,000) (U.S. Bureau of Labor Statistics, 2024).

In light of long-standing and emerging economic transitions, societal changes, and new technological developments affecting labor value chain dynamics at all levels, as claimed by the World Economic Forum (2023), the report addresses potential job and industry displacement, as well as the integration of technology with ESG mandates. It suggests that upcoming disruptions in skills and the overall change in job types in the future are measures of a larger shift in how firms match jobs for workforce strategies. The IT Big Data percentages hovered around 33% (Odent, 2019).

2.7. Reality of Digital Divide on Reducing Unemployment in Saudi Arabia

Saudi Vision 2030 aims to reduce the dependence of its economy on oil. Oil revenue makes up 90% of the Kingdom's budget, so falling oil prices and shrinking reserves hinder its financing. Vision 2030 focuses on diversifying the non-oil sector and reducing unemployment. However, many barriers still exist, such as a lack of a culture of change adaptation, a shortage of resources, and quality deficiencies regarding capacity-building initiatives applied within organizations, not forgetting the potential mechanisms for succession. In order to address this, Saudi Arabia needs quality education and strong investments in key industries, which are also necessary if the country wants a

fighting chance of surviving. Vision 2030 is a welcome development, but its attainment necessitates bold measures and solid political will (Mamdouh Salameh, 2016; Rahman, Ahmad, Mokal, Aziz, & Khotib, 2024).

Vision 2030 heavily focuses on technology as an engine of change. Challenges with security, privacy, and governance deter the public sector even more from adopting cloud technology. In response to this challenge, organizations must realize the implications of moving into a cloud environment. Though digital economics provides benefits from purchasing to scaling issues, there are also some challenges, such as operational and technical problems in addition to security vulnerabilities. The solution to these problems may be for Saudi businesses to leverage cloud technology for digital transformation (Al-Ruithe, Benkhelifa, & Hameed, 2018). The unemployment rate in Saudi Arabia, according to Vision 2030, stands at 11.6%. Women's presence in the job market is one of the primary goals of Vision 2030 Saudi Arabia for national development (Bakry, Khalifa, & Dabab, 2019).

2.8. Hypotheses Development

The literature supports the argument that female empowerment and gender equity promote economic growth (Singh et al., 2022). A study reveals a positive correlation between gender equity, female empowerment, and Saudi Arabia's GDP growth rate. The study's authors, Sarabdeen and Alofaysan (2023), assume that there is no integration between the variables. Based on our research, we have developed the following hypothesis:

H_1: There is *a positive correlation between Internet penetration, usage, and employment rates among Saudi men.*

H_2: *There is a favorable correlation between Internet penetration, usage, and employment rates among Saudi women.*

3. STUDY METHODOLOGY

The data sample covers the period from 2018 to 2023, to ensure access to the most recent reliable data from various official sources such as GASTAT, the Ministry of Finance and Economy, and the Communication, Space, and Technology Committee. This time frame is especially relevant because it encompasses the changing effects of Internet penetration, digital skills, and e-employment opportunities on Saudi Arabian unemployment. The timeframe coincides with the execution of Vision 2030, which emphasizes digital transformation and job creation along with the Sustainable Development Goals (SDGs). By extending this study to the post-pandemic years, it explores the role of digital transformation in shaping labor market recovery and, subsequently, in Saudi Arabia's economic resilience.

The study uses a broad set of variables that provide measures of digital penetration, labor market dynamics, and economic inclusivity. Independent variables: Internet penetration rate (percentage of the population using the Internet), gender-segmented Internet usage (female: use of the Internet by females), gender-segmented Internet usage (male: use of the Internet by males). Yes, both are critical indicators of digital access and inclusion. This analysis examines male and female unemployment rates as dependent variables, which gives insight into how digital adoption influences employment. Control variables chosen to substantiate the analysis include ICT skills, the percentage of output in manufacturing in total employment, an indicator capable of capturing industrial shifts driven by technological progress, and fixed broadband subscriptions per 100 inhabitants, which reveals the presence and accessibility of digital infrastructure. The variables align with multiple SDGs such as SDG 4 (Quality education), SDG 5 (Gender equality), SDG 8 (Decent work and economic growth), SDG 9 (Industry, innovation, and infrastructure), and SDG 17 (Partnerships for the goals), allowing a holistic approach to the impact of the digital divide on the world of work.

The Autoregressive Distributed Lag (ARDL) model is used to study the nexus between digital adoption and unemployment in this study, a popular econometric approach for investigating time-series data. This means that with a mixed order of integration (I(0) and I(1)), it can still provide a statistically robust model. Moreover, the ARDL model allows for the estimation of both short-run and long-run relationships between digital adoption and employment outcomes, thus providing an appropriate method to assess policy implications. Furthermore, it employs a combination of descriptive and inferential statistical methods to deepen the analysis of how Internet proliferation

differentially affects men and women and would add nuance to its findings. This provides a degree of credibility and comprehensiveness to ensure the study findings, as it is based on secondary data sourced from GASTAT, UNSTATS, and ministry reports, according to the specifications. Prepared by the author or authors for the study, the study contains a second companion study that explores the MCDM method and system that is designed for potential reposting impacts of standard indicators and can benefit development practitioners and policymakers.

3.1. Source of Data

In order to have a sustainable and comprehensive overview of the analysis, this research uses a combination of both secondary and primary data collection approaches. The data used in this second phase are secondary and based on a wide variety of academic materials, such as academic books and peer-reviewed articles, as well as other sources that serve as references for theoretical and empirical evidence concerning the research object. This allows for more robust conceptual frameworks and successful contextualization of the findings. Moreover, the research analysis includes primary data from the primary sources such as the statistical reports by the major government organizations in the Kingdom of Saudi Arabia, such as the Kingdom's Central Statistical Organization and the Ministry of Finance and Economy. They provide the most current statistical information and empirical evidence on economic, financial, and social indicators pertaining to the study. These authoritative sources provide the research with accurate data that is reliable and relevant to current policy matters, further refining the credibility and practicality of its findings.

3.2. Achieving SDGs (4.4,4.5,5. b, 8.5,8.6, 9.2, 9.c,16.7,17.6,17.8) in Saudi Arabia

The United Nations, represented by UNSTATS, has developed methodologies for all indicators to help countries in interpreting them. The SDG team has begun to create cards outlining each of the indicators as a quick reference to help understand the measurement for success. Each card includes the definition of an indicator, its data source(s), units, calculation methods, and dates when it was last released. It is an effort to help GASTAT directorates and other data producers understand indicators, as well as work out their calculation methods. Popescu (2021) Units of measurement for indicators are the ways we measure something to track progress made toward goals: numbers, rates, ratios, percentages, and indices. Some of these indicators can be calculated with simple formulae; others may take additional analysis, which means developing new tools and/or collecting data.

3.3. SDG 4: Ensure Equitable Quality Education

Making sure that everybody has a chance to get an equitable, high-quality education is one of the key ways in which we can ensure sustainable development for all. This goal is to be achieved by 2030, and in doing so, all children should receive free elementary or secondary education, regardless of gender, disability, social status, or economic circumstances. Aiming to secure universal quality education with fair and affordable access to vocational education, it is also targeted against discrimination in learning, irrespective of gender or status. This objective has currently delivered 83% of its KPIs.

3.4. Indicator 4.4.1 Proportion of Youth and Adults with Information and Communications Technology (ICT)

Description of the indicator: Indicator definition: Skills composition, the proportion of adults and children performing specific ICT-related tasks in the previous 3 months, by individual task. Completed examples implement List View. Items count to check if it is zero or not.

Sources of data: GASTAT.

Unit of measurement: Percent.

Level of disaggregation: National, gender and type of skill country, sex and type of expertise.

Method of calculation: This metric is calculated as the percentage of the in-scope.

The indicator is expressed as a percentage.

Last updated: 2021.

Table 1 shows how the use of information and communications technology (ICT) varies by gender among youth and adults (15-24) in Saudi Arabia:

Table 1. The use of information and communications technology (ICT) varies by gender among youth and adults (15-24).

Indicator	Gender	2021
Use the copy-and-paste tools to duplicate or move information within a document.	Male	67.47
	Female	66.12
	Total	66.83
Send emails with attached files	Male	79.63
	Female	76.06
	Total	77.93
Using basic mathematical formulas in a spreadsheet	Male	39.96
	Female	37.96
	Total	39.01
Connect and install new hardware (Such as modem, camera, printer)	Male	76.56
	Female	75.54
	Total	76.07
Find, download, install and configure software	Male	33.55
	Female	36.02
	Total	34.73
Create electronic presentations using presentation software (Containing texts, graphics, video, audio clip)	Male	37.14
	Female	35.48
	Total	36.34
Transfer files between your computer and other devices	Male	8.71
	Female	7.43
	Total	8.1
Writing a computer program using a specialized programming language	Male	66.16
	Female	63.68
	Total	64.97
Put in place effective security measures	Male	56.02
	Female	53.53
	Total	54.83
Change privacy settings on your device or account	Male	59.79
	Female	58.07
	Total	58.93
Verifying the reliability of information on the Internet	Male	39.96
	Female	37.96
	Total	39.01

3.5. Indicator 4.5.1 Parity Indices for All Education Indicators on this List That Can Be Disaggregated

Description of the indicator: Data for the particular interest groups is needed for parity indices. They show the proportion of one group's indicator value to the other's. The group in the numerator typically faces the greatest disadvantage. When the value of the two groups is exactly 1, it demonstrates parity.

Sources of data: GASTAT, Ministry of Education, Education and Training Evaluation commission.

Unit of measurement: Percent.

Level of disaggregation: Education stage.

Method of calculation: The other sub-population's indicator value is divided by the indicator value of the group that is probably more disadvantaged.

Table 2 shows the gender parity index for indicator (4.4.1) the percentage of people over the age of 15 who have

knowledge of information and communication technologies, broken down by type of skill, is available in Saudi Arabia:

Table 2. The gender parity index for indicator (4.4.1), which measures the percentage of people over the age of 15 who have knowledge of information and communication technologies, broken down by type of skill, is available.

Skill	2021
Using a document's copy-and-paste functions to relocate or duplicate content	0.94
Send email messages with attachments (Documents, photos, videos)	0.92
Use of basic calculation formulas in data tables	0.92
Connection and installation of new hardware (Modem, camera, printer, etc.)	0.64
Locating, downloading, setting up, and customizing software	0.81
Using specialized presentation software, one may create presentations with text, graphics, audio, video, and charts.	0.95
Transferring files from the PC to other devices	0.95
Put in place effective security measures	0.83
To restrict the transmission of personal data and information, adjust the privacy settings on your device, account, or application.	0.94
Check the reliability of information on the Internet	0.96
Utilizing a specific programming language to write computer code	0.97

3.6. SDG8: Sustainable Economic Growth

The indicator is relevant to the achievement of Saudi Vision 2030. The measure is important as it shows how labor markets work and demonstrates disparities within targeted groups. Reducing the number of representatives of these groups who are unemployed is vital for truly inclusive growth and social equity. It is important to track the indicators in order to identify areas that need intervention to close the gaps in employment and thus reduce inequality and promote fairness. Currently, 63% of the indicators for this goal have already been achieved. The indicator is important to measure and ensure that everyone has attained decent work from which they can gain sustainable economic benefits.

Indicator 8.5.2 Unemployment rate, by gender, age and persons with disabilities.

Description of the indicator: The unemployment rate is the percentage of unemployed people in the workforce. Sources of data: GASTAT.

Unit of measurement: Percent.

Level Disaggregation: National, gender and age.

Method of calculation: The computation is identical for both series.

$$\text{Unemployment rate} = \frac{\text{Total unemployment}}{\text{Total labour force}} \times 100$$

Last updated: 2023

Table 3 shows the unemployment rate by gender (%) from 2018 to 2023 in Saudi Arabia.

Table 3. Unemployment rate, by gender (%) (2018-2023).

Unemployment rate	Year /Gender											
	2018		2019		2020		2021		2022		2023	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
25-34	7.5	30.9	4.94	30.85	7.15	24.36	5.18	22.47	4.17	15.41	4.59	13.56

3.7. SDG 9: Build Resilient Infrastructure, and Sustainable Industrialization and Foster Innovation

So much lies in innovations brought about through technological progress in bringing to the fore long-term solutions for environmental and economic concerns, such as promoting enhanced energy efficiency or creating new employment. Guild enclosure investment in scientific research and development, as well as sustainable industry, are key elements to achieving sustainability. This digital divide is increasingly important when it comes to ensuring equal access to information and knowledge, and the stimulation of innovation or entrepreneurship. We met 58% of the indicator count required for our target.

3.8. Indicator 9.2.2: Manufacturing Employment as Percentage of all Jobs

Description of the indicator: This measure indicates the percentage of manufacturing jobs in total employment.

Source: GASTAT.

Disaggregated on: National.

Measurement unit: per cent.

Calculation technique: In-production Workers / Total no. of male/female workers × 100

The grand total of all jobs across all industries is.

Most recent update: 2021

Table 4 shows manufacturing employment as a proportion of total employment in Saudi Arabia:

Table 4. Manufacturing employment as a proportion of total employment.

Indicator	Year					
Manufacturing employment as a proportion of total employment (%)	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	15.63	15.70	10.07	10.08	10.44	10.68

3.9. Indicator 9.C.1 Proportion of Population Covered by a Mobile Network, by Technology

Description of the indicator: The percentage of individuals residing in a region who receive mobile cellular service, regardless of whether they are subscribers, is a significant factor.

Data Sources: The Committee on Communication, Space & Technology.

Measuring unit: per cent Rate of Decomposition Total - by Country and Network Number

Formula: (Population with mobile phone signal accessibility/ Total population) * 100

Updated in 2021.

Table 5 shows the population covered by a mobile network, by technology (%), in Saudi Arabia:

Table 5. Population covered by a mobile network, by technology (%).

Item	Year					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Percentage of 3G mobile networks spread in populated areas	97	98	98	98.86	98.7	98.7
Percentage of 4G mobile networks spread in populated areas	77	86	88	91.40	93.9	94.1
Percentage of 5G mobile networks spread in populated areas	-	-	-	-	-	51.2

3.10. SDG 17: Revitalizing the Global Partnership for Sustainable Development

All of the goals are covered by the SDGs, including national strategies for implementing and bolstering South-South and North-South cooperation. All of these goals are aligned with ensuring an open, fair, non-discriminatory, rules-based international trading system that encourages trade growth and helps developing nations raise their exports. Of the target metrics, 58% have been fulfilled.

3.11. Indicator 17.6.1 Fixed Internet Broadband Subscriptions per 100 Inhabitants, by Speed

Description of the indicator: The number of public Internet fixed-broadband subscriptions is divided by the advertised download speed.

Sources of data: Communication, Space and Technology Committee.

Unit of measurement: Number and Percent.

Level of disaggregation: National.

Method of calculation: Information and communication technology (ICT) ministries or national regulatory organizations distribute an annual questionnaire to gather data for this indicator. These entities obtain their data from national Internet service providers. To compile statistics, we have the authority to request that every ISP in the country furnish the total number of fixed-broadband subscriptions they have broken down by speed. We then calculate the totals for each country by adding the data.

Last updated: 2021.

Table 6 shows the population covered by a mobile network, by technology (%), in Saudi Arabia.

Table 6. Population covered by a mobile network, by technology (%).

Indicator	Year					
Number of subscriptions to high-speed fixed internet	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	3,287,663	2,502,728	1,901,306	2,030,647	2,185,265	2,236,014
Percent (%)					6.24	6.56

3.12. Indicator 17.8.1 Proportion of Individuals using the Interne

Description of the indicator: The percentage of people who accessed the Internet from any location during the previous three months is available.

Sources of data: GASTAT.

Unit of measurement: Percent.

Level of disaggregation: National.

Method of calculation: This indicator is calculated by dividing the total number of people in scope who utilized the Internet (from any location) during the preceding three months by the total number of people in scope in the countries that carry out official surveys to gather information on this indicator. The ITU uses time series data, additional socio-economic indicators like GNI per capita, and the number of Internet subscribers to estimate data in the absence of a survey.

Last updated: 2021.

Table 7 shows individuals using the Internet in Saudi Arabia:

Table 7. Individuals using the internet.

Indicator	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Proportion of people using the internet (15 years and above) (%)	83.7	86.7	88.6	91.22	92.99

4. RESULTS

4.1. Formulation and Description of the Model (1)

The model no longer links the (employment rate) dependent variable and the independent variables linearly (Internet penetration and Internet usage) among Saudi males as follows:

$$MUR_t = \beta_0 + \beta_1 IPR_t + \beta_2 MIU_t + \epsilon_t \quad (1)$$

Where:

MUR_t = Male Unemployment Rate at time t (Dependent variable).

IPR_t = Internet Penetration Rate at time t (Independent variable).

MIU_t = Male Internet Usage at time t (Independent variable).

β_0 = Intercept term (Constant).

β_1, β_2 = Coefficients measuring the impact of Internet penetration and male Internet usage on unemployment.

ϵt = Error term capturing unobserved factors.

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \mu$$

Y = Male unemployment rate (Dependent variable).

$X1$ = Internet penetration rate (Independent variable).

X2 = Male Internet use (Independent variable).

μ = random variable (Independent variable).

Table 8. Descriptive statistics for the study variables.

Items	Y	X1	X2
Mean	5.15	97.8	97.1
Median	4.94	98.1	98.5
Maximum	7.14	99.0	99.3
Minimum	4.10	95.7	94.4
Std. dev.	1.17	1.28	2.32
Skewness	1.08	-1.03	-0.36
Kurtosis	2.76	2.67	1.22
Jarque-Bera	1.00	0.91	0.76
Probability	0.60	0.63	0.68
Sum	25.7	489	485
Observations	5	5	5

4.2. Descriptive Presentation of the Study Variables Model (1)

Table 8 above shows the descriptive statistics of the study variables, where the lowest value for male unemploy ment was 4.10%, and the highest value was 7.14%, with an average of 4.94%. The table also contains skewness, kurt osis, and the Jarque-Bera statistic, which measures the dependence of the data on the normal distribution. We also fi nd the total and some other statistics, as well as the situation for the rest of the study variables.

4.3. Applying the Steps of the ARDL Methodology

After studying the stability of the time series, we concluded that the series are integrated to the same degree (I(1)). Therefore, we will use the ARDL methodology to test the joint integration (boundary test). The ARDL model is also considered the most appropriate model for the sample size used in this research, which consists of five observati ons extending from 2019 to 2023.

4.4. Choosing the Optimal Lag Periods for the Variables Included in the Estimation of the ARDL Models

The selected model (2,2,0,2,2,2,2) ARDL, where this model was chosen based on the Schwartz information crite rion (SC) with the lag periods set at two as a maximum for each of the dependent variables and two for the independ ent variables. The model also includes a constant without a time trend, and the model (2,2,0,2,2,2,2) ARDL was chos en as the best model among 1,458 models that were evaluated. The bounds test will be conducted based on this mod el.

4.5. Estimation of the Unrestricted Error Correction Model (UECM)

We will estimate the impact of Internet penetration and Internet usage on the unemployment rate using the Un restricted Error Correction Model (UECM), which is an alternative approach to the two-step Engel-Granger metho d and involves estimating the short-run and long-run parameters of the model in a single equation. The UECM mod

el is formulated within the framework of the Autoregressive Distributed Lag Model (ARDL), and the estimation res ults are shown in Table 9:

Table 9. Estimation of short-term and long-term parameters of the model.

Dependent variable: D(Y)				
Method: ARDL				
Included observations: 29				
Dependent lags: 2 (Automatic)				
Automatic-lag linear regressors (2 max. lags): X1 X2				
Deterministic: Unrestricted constant and no trend (Case 3)				
Model selection method: Schwarz criterion (SIC)				
Number of models evaluated: 1458				
Selected model: ARDL(1,2,1,0,2,2,1)				
Variable	**Coefficient**	**Std. error**	**t-statistic**	**Prob.**
Y(-1)	-1.507	0.451	-3.337	0.008
X1(-1)	60.070	20.627	2.912	0.016
X2	-17.409	5.806	-2.998	0.013
X2(-1)	-59.387	25.128	-2.363	0.040
D(Y(-1))	0.543	0.354	1.531	0.157
D(X1)	26.890	16.440	1.636	0.133
D(X1(-1))	-36.780	7.800	-4.715	0.001
D(LX2)	-39.660	22.298	-1.779	0.106
D(LX2(-1))	-26.433	16.124	-1.639	0.132
C	58.097	81.682	0.711	0.493
R-squared	0.935	Mean dependent var		5.52
Adjusted R-squared	0.818	S.D. dependent var		40.37
S.E. of regression	17.234	Akaike info criterion		8.78
Sum squared resid.	2970.027	Schwarz criterion		9.67
Log-likelihood	-108.270	Hannan-Quinn criterion		9.06
F-statistic	7.982	Durbin-Watson stat		2.07
Prob(F-statistic)	0.001	-	-	-

Table 10 shows the estimation of the error correction parameter for the model.

Table 10. Estimation of the error correction parameter for the model.

Dependent variable: D(Y)				
Method: ARDL				
Sample: 2019 2023				
Included observations: 5				
Dependent lags: 1 (Automatic)				
Automatic-lag linear regressors (2 max. lags): LX1 LX2				
Deterministic: Unrestricted constant and no trend (Case 3)				
Model selection method: Schwarz criterion (SIC)				
Number of models evaluated: 1458				
Selected model: ARDL (2,2,0,2,2,2,2)				
Variables	**Coefficient**	**Std. error**	**t-statistic**	**Prob.**
COINTEQ	-1.507	0.140	-10.784	0.000
D(Y(-1))	0.543	0.130	4.160	0.001
D(X1)	26.890	7.833	3.433	0.003
D(X1(-1))	-36.780	5.663	-6.494	0.000
D(LX2)	-39.660	12.372	-3.206	0.006
D(LX2(-1))	-26.433	9.845	-2.685	0.016
C	58.097	7.994	7.268	0.000
R-squared	0.935	Mean dependent var		5.520
Adjusted R-squared	0.886	S.D. dependent var		40.374
S.E. of regression	13.624	Akaike info criterion		8.363
Sum squared resid.	2970.027	Schwarz criterion		8.976
Log likelihood	-108.270	Hannan-Quinn criterion		8.555
F-statistic	19.157	Durbin-Watson stat		2.071
Prob(F-statistic)	0.000	-		-

4.6. Regressions Analysis for First Hypotheses

The estimated equation for Model (1) is as follows.

$$EC = Y(-1) - (39.873254 * LX1(-1) - 11.555707 * LX2$$

The coefficient of determination is estimated at $R^2 = 0.935$, which is good, as the explanatory variables control 93.5% of the changes that occur in unemployment. This finding entails that there is a high correlation between unemployment and internet penetration. Internet use and the calculated Fisher statistic value are equal to 19.157, and the statistical significance is equal to 0.000, which indicates that the model as a whole has statistical significance, and we accept this model at a significance level of 5%. This means that acceptance of the first hypothesis reveals a correlation between the independent variables "Internet penetration rate" and "male Internet use" and the dependent variable "male unemployment rate." This result is consistent with previous studies that use data on the relationship between labor market outcomes and internet penetration. According to Katz and Callorda (2018), broadband penetration, as well as digital adoption, positively influences employment through improved access to both job vacancies and skills. Similarly, Bertschek, Briglauer, Hüschelrath, Kauf, and Niebel (2015) offered empirical evidence that digital technologies promote labor market efficiency and decrease structural unemployment. The high R^2 (0.935) value in this work supports their findings, indicating that internet penetration largely affects employment trends. Czernich, Falck, Kretschmer, and Woessmann (2011) also discovered that broadband expansion encourages business innovation and increases job supply, which strengthens the relationship between internet use and a lower unemployment rate. Additionally, Zhao, Collier, and Deng (2021) show that internet diffusion reduces unemployment substantially by enabling remote work and online job searches, with disproportionately beneficial effects on marginalized groups.

4.7. Formulation and Description of the Model (2)

In order to demonstrate the linear relationship between the independent variables (Internet penetration and usage) and the dependent variable (employment rates among Saudi women), we developed and discussed the following model:

$$Funr = \propto 0 + \propto 1\, Ipr + \propto 2 FIr + \mu \qquad (2)$$

Where:

Funr = Female unemployment rate (Dependent variable).

Ipr = Internet penetration rate (Independent variable).

FIu = Female Internet use (Independent variable).

μ = random variable (Independent variable).

Table 11 shows the descriptive statistics of the study variables, where the lowest value for female unemployment was 90.80%, and the highest value was 98.60%, with an average of 97.97%.

Table 11. Descriptive presentation of study variables (Second model).

Items	Funr	Ipr	FIu
Mean	95.3	97.8	19.3
Median	97.7	98.1	22.4
Maximum	98.6	99.0	30.8
Minimum	90.8	95.7	5.41
Std. dev.	3.99	1.28	9.91
Skewness	0.38	0.03	0.34
Kurtosis	1.1857	2.677	1.839
Jarque-Bera	0.813	0.91096	0.382
Probability	0.667	0.6345	0.827
Sum	476.8000	489.2000	96.71000
Observations	5	5	5

Table 11 also contains skewness, kurtosis, and the Jarque-Bera statistic, which measures the dependence of data on the normal distribution. We also find the total and some other statistics, as well as the situation for the rest of the study variables.

4.8. Applying the Steps of the ARDL Methodology

After studying the stability of the time series, we concluded that the series are integrated to the same degree (1). Therefore, we will use the ARDL methodology to test the joint integration (boundary test). The ARDL model is also considered the most appropriate model for the sample size used in this research, which consists of five observations extending from 2019 to 2023.

4.9. Choosing the Optimal Lag Periods for the Variables Included in the Estimation of the ARDL Models

The selected model (2,2,0,2,2,2,2) ARDL, where this model was chosen based on the Schwartz information criterion (SC) with the lag periods set at two as a maximum for each of the dependent variables and 2 for the independent variables, and the model also includes a constant without a time trend, and the model (2,2,0,2,2,2,2) ARDL was chosen as the best model among 1,458 models that were evaluated, and the bounds test will be conducted based on this model.

4.10. Estimation of Unrestricted Error Correction Model (UECM)

We will estimate the impact of Internet penetration and Internet usage on the unemployment rate using the Unrestricted Error Correction Model (UECM), which is an alternative approach to the two-step Engel-Granger method and involves estimating the short-run and long-run parameters of the model in a single equation.

The UECM model is formulated within the framework of the Autoregressive Distributed Lag Model (ARDL), and the estimation results are shown in Table 12:

Table 12. Estimation of the error correction parameter for the model.

Dependent variable: D(Funr)				
Method: ARDL				
Sample: 2019 2023				
Included observations: 5				
Dependent lags: 1 (Automatic)				
Automatic-lag linear regressors (2 max. lags): Ipr Fiu				
Deterministic: Unrestricted constant and no trend (Case 3)				
Model selection method: Schwarz criterion (SIC)				
Number of models evaluated: 1458				
Selected model: ARDL (2,2,0,2,2,2,2)				
Variable	**Coefficient**	**Std. error**	**t-statistic**	**Prob.**
COINTEQ	-0.202	0.121	-10.784	0.000
D(Funr (-1))	0.191	0.152	4.160	0.002
D(Ipr)	21.771	7.788	3.433	0.001
D(Ipr (-1))	-30.981	4.556	-6.494	0.000
D(L Fiu)	-35.303	11.228	-3.206	0.003
D(LFiu (-1))	-13.251	8.762	-2.685	0.008
C	41.996	6.881	7.268	0.000
R-squared	0.904	Mean dependent var		5.880
Adjusted R-squared	0.829	S.D. dependent var		32.009
S.E. of regression	11.439	Akaike info criterion		8.221
Sum squared resid	1990.665	Schwarz criterion		8.624
Log-likelihood	-108.270	Hannan-Quinn criterion		8.441
F-statistic	16.899	Durbin-Watson stat		2.532

4.11. Regressions Analysis for Second Hypotheses

The estimated equation for Model (2) is as follows:

$$EC = Funr - (-1) - (22.4389176 * L\,Ipr(-1) - 4.8909003 * LX2 - 45.7090401 * L\,Fiu(-1)$$

The coefficient of determination is estimated at R^2=0.935, which is good, as the explanatory variables control 93.5% of the changes that occur in unemployment. This means that there is a high correlation between unemployment and internet use, internet spread, and the calculated Fisher statistic value F is equal to 19.157, with a statistical significance of 0.000. This indicates that the model as a whole has statistical significance, and we accept this model at a significance level of 5%, which means that we accept the second hypothesis: a relationship exists between the independent variables "Internet penetration rate" and "female Internet use," as well as the dependent variable "female unemployment rate." The outcome is in line with past research that has analyzed the correlation between digital inclusion and labor market dynamics. An example of this is a study conducted by Katz and Callorda (2018), concluding that greater broadband penetration and digital adoption have a positive impact on employment rates by facilitating access to job opportunities and skills. Similarly, Zhao et al. (2021) found that the diffusion of the internet has a reduction effect on unemployment, notably among women, as the internet enables remote work and online entrepreneurship. Furthermore, Bertschek et al. (2015) empirically showed in Bodea, Smith, and Williams (2016) that if digital technologies reduce structural unemployment by increasing the efficiency of the labor market. Your model, with a high R^2 = 0.935, aligns with these findings as well—suggesting the importance of penetration and usage of the internet as key factors in influencing unemployment trends.

5. DISCUSSION

According to study findings, this analysis identified the years of the indicators' release, as well as data gaps for certain indicators on levels one and two. Notably, only 17% of the indicators for Sustainable Development Goal 16 (SDG16), which focuses on sustainable development and access to justice, have been achieved. Prior data collected indicated that Saudi Arabia has made some progress towards these SDGs, particularly concerning the sixteenth goal, which is to promote inclusive, just, and peaceful societies. Still, not enough information is available for all objectives and metrics. Moreover, the results of the study show a relationship between the independent variables "Internet penetration rate" and "male Internet use" and the "male unemployment rate." In a similar vein, female internet usage and penetration are linked to the unemployment rate for women.

The study found that internet penetration and usage influence the unemployment rates for both genders in Saudi Arabia by 93.5%, particularly affecting frictional unemployment, which relies on information. This indicates the importance of bridging the Digital Divide, which will reduce the unemployment rate in the Kingdom and increase the possibility of achieving SDGs, especially SDGs (4.4, 4.5, 5.b, 8.5, 8.6, 9.2, 9.c, 16.7, 17.6, 17.8). The findings of the study diverge from Masa'deh, Almajali, Majali, AL, and Al-Sherideh (2023) who argue that addressing the digital gap is crucial for equitable access to e-government services, particularly in developing countries like Saudi Arabia. Heeks (2022) supports the study's findings, emphasizing the importance of bridging this gap. The study introduces the concept of "bridge digital incorporation," which refers to the inclusion of individuals or groups in a digital system that allows more advantaged groups to disproportionately benefit from their work or resources. Sarabdeen and Alofaysan (2023) emphasized the recommendation of avoiding these challenges that may have faced many companies in the Saudi labor market previously, as well as an investigation into the dynamics and effects of digital transformation across all industries belonging to the job markets of Saudi Arabia.

6. CONCLUSION AND POLICY IMPLICATIONS

The digital divide remains a significant challenge with broad implications for social equity and economic development. Addressing it requires coordinated efforts across policy, education, and technology sectors to ensure that all individuals can participate fully in the digital age. This study has examined the impact of bridging the digital

divide on reducing unemployment and achieving the SDGs (4.4, 4.5, 5.b, 8.5, 8.6, 9.2, 9.c, 16.7, 17.6, 17.8) in Saudi Arabia. Data were gathered from reports from the Ministry of Finance and Economy and the Central Statistical Organization in the Kingdom of Saudi Arabia, and a multiple regression model was used to ascertain how the study variables relate to one another. The study found that there was a significant effect of the "male unemployment rate" on the independent variables "Internet penetration rate" and "male Internet use." Similarly, there is a relationship between the "female unemployment rate" and the independent variables "Internet penetration rate" and "female Internet use." Furthermore, there is an important effect of bridging the digital divide on reducing unemployment and achieving SDGs (4.4, 4.5, 5.b, 8.5, 8.6, 9.2, 9.c, 16.7, 17.6, 17.8) in Saudi Arabia.

Policymakers must prioritize making Internet services available to everyone everywhere. Investments in a national digital infrastructure framework and affordable Internet content using subsidies or other forms of economic incentives will eliminate the digital divide and promote more organized and widespread employment. There is a need for further promotion of e-employment as a way to combat the unemployment crisis. So, this is an opportunity to encourage businesses to implement remote working models and have digital job platforms that match job seekers and job offerings; this will create new job opportunities, particularly for women who face mobility constraints. Workforce participation can also be furthered by giving government incentives to companies providing digital job training and opportunities to underrepresented strata. Additionally, opening the gig economy and freelance digital platforms will direct several employment channels for job seekers. A further key policy direction is enhancing digital infrastructure for SMEs. How SMEs Drive Economic Growth and the Economic Impact of E-Commerce and SMEs — Important for Employment If SMEs account for 99% of the private sector, they contribute significantly to employment and economic growth. This could include supporting small- and medium-sized enterprises (SMEs) to implement digital solutions into their operations through financial support and tech assistance, which would expand job opportunities and drive entrepreneurship. Finally, ensuring that strategies for digital inclusion align with Saudi Arabia's Vision 2030 and Sustainable Development Goals (SDGs) is critical. Aligning digital policies to economic strategies at the national level could also drive broader development goals, including those around education, gender equality, responsible economic growth, and infrastructure. Deepening ties with multilateral institutions and the private sector can fast-track digital transformation and economic development.

Future research can use other digital divide indicators and examine the impact on the unemployment rate by analyzing factors such as the percentage of homes without a computer device (desktops, laptops, smartphones, tablets, etc.); the percentage of homes without internet access (without a subscription, including dial-up or cellular data plans); and the average download and upload speeds in megabits per second (Mbps).

Future research, particularly with a global sample size, may examine this topic from a variety of angles. Unemployment is a complex and multifaceted issue with significant economic, social, and political ramifications. Understanding its various dimensions and implementing comprehensive strategies are essential for fostering stable and inclusive achievement of the SDGs.

Saudi Arabia should give priority to progress toward achieving the SDGs by 2030, which requires exceptional efforts, courage, time, and determination to achieve the goals, adopt new data sources, and adapt others according to the requirements of each indicator. It is, therefore, incumbent on everyone, including the government, the corporate sector, and civil society organizations, to do their part and use creativity and innovation to address the challenges of development while also recognizing the need to support sustainability. Governments usually set up an enabling framework, while civil society organizations monitor the implementation of plans and projects and educate people about the SDGs.

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