Moderating Role of Knowledge-Sharing on the Nexus of Digital Business and Natural Resources

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Abstract
This study conducts an empirical analysis of the effects of the procedure of transforming digital on natural resource rents in the private and public sectors. In our paper, we analyze the changes in total natural rents (rents from coal, mineral, natural gas, and forest) by digital businesses (e-commerce, involving shopping online, turnovers e-commerce, trading on e-commerce web, and business electronically, involving the use of customer relationship management (CRM), and cloud usage). From 2011 to 2019, a sample of 26 countries from the European Union was examined using various econometric approaches. Our estimation results demonstrate that digital businesses cause a rise in overall natural rents. More precisely, the rents for coal and gas appear to be more influenced by an enterprise’s integration of digital technologies. On the other hand, digitalization in the business sector tends to lower coal rents and mineral and woodland rents. Notably, knowledge-sharing is the most crucial component to promote the efficiency of digitalization in preventing natural rent-seeking.

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Introduction

Numerous diverse tendencies in various global regions have complicated the rents of natural resources. For instance, among the 17 goals outlined by the United Nations (UN) to attain ecological sustainability, environmentally responsible production and consumption are some of the most important ones (UN, 2019). Kuwait, Colombia, and Russia are some of the most resource-intensive nations in the world. Natural resource rents are generally modest in developed countries like Hong Kong, France, Finland, Japan, Australia, Germany, Italy, and New Zealand (Canh et al., 2020). Certain nations, such as Canada, China, the Philippines, and Russia, seem to decline, while Cambodia and Vietnam look to be on the rise. The “natural resource curse” problem is steadily growing more severe and calls for more specialized research in numerous fields and geographical areas, particularly in Europe, where the adverse environmental effects of resource consumption are getting worse (European Environment Agency, 2020a). When resource demand in Europe exceeds local supply, nations become dependent on and compete for resources from other countries, raising concerns about the security of the region’s long-term resource supply and creating the possibility of future wars (European Environment Agency, 2020a). According to a warning from the European Environment Agency (2020b), this region will not be able to meet its 2030 targets if significant effort is not handled with the alarming rate of habitat destruction over the next 10 years, growing global warming effects, and overuse of energy resources.

Papers on the curse of natural resources augment dramatically over time. New scholarship has highlighted the significance of digitalization in altering the industrial process and thus boosting economic growth. The procedure of integrating digitized infrastructures and technology into various facets of the enterprise, the economy, and the community is known as digitalization, according to Autio et al. (2018). Currently, a lot of people are aware of how information technology is used in industry and commerce. As the industrial revolution advanced, every economic aspect became increasingly digital. The sector can evolve more quickly thanks to digitization, making cross-border trading easier and providing new investment options for enterprises. Digitization can help rapidly lower countless workers’ and intermediary product values (Devold et al., 2017; Herzog et al., 2017; Pop, 2020). Additionally, the electronic data system helps international companies to reach new customers (World Economic Forum, 2021). Digitalization increases the need for well-being and ecologically conscious since it promotes financial and economic globalization, which is a crucial driver of economic development (Farhadi et al., 2012; Solomon & van Klyton, 2020; Lee & Lee, 2009; Martínez-Zarzoso & Maruotti, 2011). Digitalization will encourage customers to make environmentally friendly choices while pressuring firms to
adopt cleaner manufacturing techniques and respond to competitive demands and environmental limits by using green innovation (European Commission, 1999; International Trade Centre, 2001; Kennett & Steenblik, 2005; Sinclair-Desgagné, 2008). Digitizing, therefore, significantly impacts how natural resource rents are determined. However, there has not been any mention of the connection between digitalization and rents from natural resources in the literature up to this point.

Moreover, according to Canh et al. (2020), natural rents appear to be significantly impacted by the structural changes in the economic systems. The intricacy of the economies reflects the diversity in output or knowledge-sharing. Earlier researchers, such as Hidalgo and Hausmann (2009) and Hausmann et al. (2014), contend that knowledge has been incorporated into various nations’ production processes. The intricate arguments made by Antonelli (2011) demonstrate the connection between knowledge-sharing, acceptance of new technologies, and technology. In this research, we argue that knowledge-sharing increases the potential for the digital revolution’s deployment, hastening the consequences of digitalization on natural resource rents.

The key objective of the European Union (EU) is to transition to a digital economy, which incorporates cutting-edge technology, the advancement of artificial intelligence, and other factors into various economic sectors corresponding to the rest of the globe. The 2017 edition of Europe’s Digital Progress Report (EDPR) for EU nations shows a substantial variation in adopting electronic architecture. According to a digital economy and society index (DESI) based on digital expertise, digital technology connectivity, and internet surfing in the corporate and public sectors, Romania and Bulgaria had the lowest scores. Scandinavian nations and other minor nations, however, came out on top. Creating a plan or strategy for a digital country is required in almost all nations. Numerous efforts in data protection laws, copyright, cybersecurity, and e-commerce were adopted from 2014 to 2019. They included investments in digital services and infrastructure, research initiatives, and the digitization of business and governmental services. The EU’s DESI increased significantly from 0.43 in 2014 to 0.52 in 2019, according to the EDPR (2017). Approximately 99% of EU households had access to basic fixed broadband. The percentage of Small and Medium Size EU Enterprises (SMEs) who have used computerized technologies has continuously increased. Thirty-eight percent of internet users who use digital public services have electronically exchanged forms with the government. In general, it is believed that Europe will experience a significant digital revolution between 2012 and 2019.

At least two new ideas are brought to the field by our research. With this study, a first attempt has been made to assess how the digital revolution has affected natural rents in the European area. This study is expected to provide a more in-depth examination of how digitization and natural resource rents connect by using a variety of metrics to track the progress of digital transition in both the corporate and governmental sectors. Second, our study shows how crucial economic complexity is in determining how digitization will affect natural rents. Our analysis takes into account the variety of products and the quality of the production system as a conduit to augment the effects of digitalization on natural rents.
In contrast, earlier studies have highlighted economic complexity as a primary cause of issues with natural rents. From 2011 to 2019, we examined the statistics for 26 European Union nations for this reason. Due to the existence of cross-sectional dependence, the panel corrected standard errors (PCSE) model is primarily used. We additionally use the feasible generalized least squares (FGLS) estimation model to account for variable variance and fixed effects to verify the conclusions’ veracity. All of the model’s explanatory variables are 1 year postponed reducing the likelihood of endogeneity issues. The panel corrected standard errors (PCSE) model is primarily employed since cross-sectional dependency exists. To confirm the accuracy of the findings, we additionally use a feasible generalized least squares (FGLS) estimate model to take fixed effects and varying variations into consideration.

The remaining paragraphs are arranged in the following manner. In “Related Works and Hypothesis Development,” an analysis of pertinent literature is offered. “Empirical Methodology” presents the model, the data, and the estimation strategy; “Empirical Results” discusses the empirical results. “Conclusions” of the essay brings it to an end.

**Related Works and Hypothesis Development**

**Digitalization and Knowledge**

By digitalizing work, knowledge may be better utilized (Bouncken & Barwinski, 2021; Vuori et al., 2019), resulting in increased productivity (Chou et al., 2014; Ribeiro-Navarrete et al., 2021; Shujahat et al., 2018, 2019) and efficiency (Porter & Heppelmann, 2015). In short, digitalization should lead to improved performance, such as achieving set objectives or enhancing the expertise of individuals and organizations (Vuori et al., 2019).

In addition to the direction (sender and receiver) and content of knowledge flow, another important characteristic is the carrier (medium) by which knowledge passes from one individual to another (Vuori et al., 2019). Therefore, it is not surprising that digitalization is expected to enhance knowledge flows by providing effective tools to serve as media and enablers of knowledge. Production increases in direct proportion to the speed at which information flows within an organization (Schmenner, 2004). Therefore, the more effective and efficient the knowledge flow within an organization is, the more quickly knowledge workers are able to plan and execute their tasks (Wu et al., 2004). In support of knowledge work, technological tools and digital technologies are designed to achieve this. Franssila et al. (2016) indicate that tools are used in three domains in the digital workplace: (i) management and refinement of information by personal computers; (ii) acquisition and sharing of data and information in a networked work environment; and (iii) communication.

By making more information and knowledge readily available, digital tools provide better resources for knowledge work. However, Woods et al. (2002) contend that since human ability to interpret meaningful data has not improved, this may simultaneously lead to an information overload. Inefficiency and stress are a result of the feeling of losing control due to the abundance of information. In order to
reap the benefits of digitalization, it is vital to identify and manage the information load associated with knowledge-intensive work. There is an urgent need to develop methods suited for different processes and conventions in order for individuals to be more resilient and more capable of coping with the demands of contemporary work (Vuori et al., 2019). While the digital revolution may enhance freedom, independence, and autonomy for knowledge workers by enabling mobility, flexibility, and asynchrony, it leads to a “always-on” lifestyle in which work intrudes into leisure time. Barber and Santuzzi (2015) have identified the expectation of availability and the implicit pressure to respond immediately as being stressful factors. As a result of this situation, time management and workers’ well-being are adversely affected if they perceive that they do not have enough time to recharge between working hours.

**Digitalization and Natural Resource Rents**

There are several different economic implications of digitization, according to the research. Digitalization impacts social and economic relations as well as manufacturing and management procedures. As a result, the impact of digitalization on the usage of natural resources is complex, taking into account both positive and negative outcomes. Energy and natural resources are essential inputs for industrial manufacturing processes. More considerable carbon emissions are produced by reason of increasing levels of energy and resource use, which in turn generates more serious environmental problems. How digitization and environmental resource rents connect is examined in this research by examining how the technology has affected green consumption, manufacturing, energy efficiency, and the environment, as well as its rebound impacts on these areas.

**Influences of Digitalization on Energy Efficiency**

The development of information has been considerably accelerated by the creation and widespread use of the Internet. Thanks to faster processing speeds and a plethora of knowledge, people may learn a considerable quantity and a wide variety of topics more quickly and thoroughly—as long as they have an affordable internet connection and higher search efficiency. In addition to data collection, the quick development of big data, cloud computing, and numerous communication channels has made it possible for people to more effectively and affordably transfer and synchronize information between themselves and with other people, regardless of distance or time restrictions (Spiezia, 2011). Then, employees may use this knowledge to their advantage to increase their expertise, engage in additional R&D activities, and continually develop new professional abilities. Consequently, attempts to enhance technological innovation are favorably impacted, strengthening human capital (Ferro, 2011; Haini, 2019). There is no nation that is exempt from this influence. Instead, via more rapid information exchange, information distribution, and occupational mobility, worldwide networks, and Internet platforms promote cross-border expertise and technological spillovers. When an advanced technology system is developed, it continuously raises human resources’ worth and quickens the adoption
and dissemination of innovation through several worldwide industries (Basu & Fernald, 2007; Ceccobelli et al., 2012). Additionally, the vigorous funding growth in the modern age has enabled both the procedure of technical innovation mentioned above and the modernization of the industrial structure. New financial models and credit channels, as well as the facilitation of cross-border and time-boundary transactions between investment funds and businesses, can arise thanks to the financial sector’s usage of the Internet (Salahuddin & Gow, 2016). Additionally, the creation of financing and financing sources will offer money for R&D activities, notably for financial support of green technology investments and adherence to environmental policies (Faisal et al., 2018; Owusu-Agyei et al., 2020; Salahuddin et al., 2015; Tamazian et al., 2009).

Each stage of the manufacturing process will be more successful as the advanced level of equipment is improved, increasing the procedure’s overall effectiveness. Moreover, low-energy engineering and technology-intensive things will be replaced by high-energy sophisticated technologies (which have a strong technological component) for conventional goods, which utilize a lot of resources, according to Airehrour et al. (2016) (Li et al., 2019). Assume that the management of green product development and manufacturing is optimized, leading to increased output and market diversification. The advantages of internet technology may thus be further increased, both inside the production division of technology and between digital and non-digital businesses (Dunnewijk & Hultén, 2007). However, the varying degrees of technology and energy-intensive sectors’ production capacities and worker qualifications will result in an uneven distribution of resources, giving more efficient technology-intensive industries priority.

After that point, there will be a substantial change in the industrial structure toward concentration, which will raise the percentage of technology-intensive businesses while diminishing the share of energy-intensive and ecologically destructive industries (Qin et al., 2017). Digitization will speed up this process through two crucial transmission mechanisms involving greater competitiveness and cost-effective creative knowledge exchange across global firms, based on the remarkable advantages (Vassileva et al., 2012). Considering this, it is obvious that improving the industrial structure would boost ES efficiency while lowering energy use. Numerous earlier works of research, including Collard et al. (2005) for the French service sectors, Bernstein and Madlener (2010), Ishida (2015) and Takase and Murota (2004) for Japan, and Ren et al. (2021) for China, have shown these beneficial benefits.

Influences of Digitalization on Natural Resource Production

Digitization may inspire people and businesses to change the direction of their production, even while it cannot force them to consume less energy or reduce carbon emissions. According to Moyer and Hughes (2012), information and communication technologies (ICTs) encourage environmentally friendly consumption and production by bringing down the price of renewable energy. As “smart grids” have grown in popularity, the effective distribution of energy supply and demand has been made possible more so through digitalization. This has increased productivity and decreased transmission mistakes, which has lowered production and consumption costs. Individuals and
companies can use the grids to transact using this method. Similar to this, Verma et al. (2020) claim that the materials and energy structures will suddenly change to reflect the trend of using more sustainable energy as long as the method for the production, distribution, and assimilation of environmental assets into the current centralized energy system is improved by the successes of digitization. Because they offer more thorough information on consumption and production patterns, technological performance, and company efficiency participation, modern equipment, AI technology, or weather forecasts also contribute to this shift.

Due to the intricacy of the relationships between them, even while digitization has a beneficial influence on many aspects of finance and community, the ecosystem and the exploitation of natural resources continue to face a number of capacitive dangers. In particular, digitalization may have “rebound effects” on green innovation, energy efficiency, commerce, and economic growth. The downside of digitization and sophisticated technologies is that they might encourage the economy to create more and more as a result of their spillover effects on digital industries (Salahuddin & Gow, 2016). However, the ecology suffers as a result of this economic expansion. The successes of digitizing, like good salaries, established banking firms, efficient trade, and affordable banking deposits, may increase the overall amount of products and services consumed by households because many traditional theories demonstrate that increasing income levels will increase the usage of energy (Jalas, 2009). As a result, the ecosystem will be forced to bear even heavier responsibilities. Additionally, if energy efficiency is improved, the nominal market price may decline, leading to an increase in energy consumption (Yang & Li, 2017). Sometimes, the benefits of the digital financial system even assist the growing process, intensifying overall spending by multiples. The rebound effects might also be a result of one’s own environmentally friendly invention, which is meant to be the answer to environmental protection. Due to the fact that these innovations call for the construction of specialized infrastructures as well as the use of both “green” and “brown” inputs in industrial processes (Kemp-Benedict, 2014), eco-innovation will be associated with higher energy use and issuing (Huberty et al., 2011; Sorrell, 2007).

In reality, past experimental research has shown a positive connection between resource usage, carbon footprint, and digitalization. For instance, Salahuddin and Alam (2016) discovered that the adoption of web technologies is linked to increased power consumption in OECD nations over the long and short term. Additionally, emerging nations have demonstrated that ICTs and power usage are positively correlated (Sadorsky, 2012). The link between ICTs and US energy consumption is shown by Takase and Murota (2004). The association is further supported by Longo and York (2015)’s analysis of data for a global sample from 1990 to 2010.

We think that this link follows a non-linear process since there are many different ways to describe the implications of digitalization on energy security, both good and bad.

**H1a:** digitalization and natural resource rents are positively correlated.

**H1b:** digitalization and natural resource rents are negatively correlated.
The Role of Knowledge-Sharing

The core-peripheral structure hypothesis is suggested by Hidalgo et al. (2007) to define the distinguishing characteristics of the manufacturing process. He contends that there are two essential phases to the creation of various items. The manufacture of equipment, chemicals, and metal goods (allowing for closer product probabilities) is implied by the product core. The periphery, on the other hand, makes product suggestions like fishing, the tropics, clothing and agriculture, and mining textiles. Like energy security, economic complexity is a multifaceted term. Stern (2004) asserts that in order to understand the complexity, it is vital to take into account how the economy interacts with four important sectors: size, product restructuring, technology advancement, and input structure change. As an economy begins to grow, it mostly produces low-complexity goods, which causes EC to be characterized by periphery production. According to Lapatinas et al. (2019), the specialized nature of certain businesses makes it difficult to innovate while also having less of an impact on the environment. During the shift to a complex economy, by-products in the core will gradually replace products in the periphery (Hausmann et al., 2014; Hidalgo & Hausmann, 2009; Hidalgo et al., 2007). Additionally, heavier industries, whose product range is more diverse and unfavorable to the ecosystem, are replacing older, reliant on nature firms. This trend eventually results in larger spillovers of new industrial activity (scale effect) (Stern, 2004). Yet, due to high setup costs at this point, ecologically friendly solutions are still quite restricted (Liddle & Lung, 2010; Madlener & Sunak, 2011). The amount and intensity of natural resource energies, therefore, rise as a result of early economic complexity restructuring.

By addressing energy consumption challenges, new technical advancements can boost energy utilization optimization and result in thermodynamic efficiency (Can & Gozgor, 2017), which may result in a decrease in the amount and frequency of natural resource consumption (Stern, 2004). When the level of production scale is reached, the increase in product diversity, quality, and production system. Economic efficiency and national revenue will both rise as the economy becomes more complicated, according to Hidalgo et al. (2007). People will become more conscious of environmental concerns as their income and awareness increase (Galeotti et al., 2009; Lee & Lee, 2009; Martínez-Zarzoso & Maruotti, 2011). Additionally, businesses are aware of the necessity of converting to environmentally friendly production in order to survive and thrive in the new environment, as well as to fulfill customer demand and win societal approval (European Commission, 1999; International Trade Centre, 2001; Kennett & Steenblik, 2005; Sinclair-Desgagné, 2008). Consequently, the manufacturing process’s input structure fluctuates between “green” and “brown” entrances. In other words, as the financial problem grows, it strengthens the declining impacts of digitalization on natural resource use, minimizing the effects of environmental contamination.

Countries must carry out strategic innovations, create new industries, and embrace the transformation process when the economic complexity is at its highest point, as it were, when all production and product diversities and capacities are totally employed. Stern (2004) asserts that at this time, the system would change from resource-consuming heavy manufacturing to boost the service and
production factors, switching from the center to the perimeter of the product structure (Dinda, 2004). As a result, high-intensive sectors will eventually replace those that depend heavily on natural resources. Institutions begin to anticipate sustainable growth as a result of this process. Additionally, earlier research in the literature demonstrates the advantages of digitalization for productivity expansion. Nonetheless, depending on the amount of technology, these consequences may not occur. An indicator that gauges the caliber of exporting nations’ goods was created by Hausmann et al. (2007) to show which nations do better when exporting more complex items. As a gauge of the sophistication of a product and its production, the subject of economic complexity is receiving more and more attention as a way to consider the variance in the affects of digitizing on natural resource rents.

In light of our discussion, we postulate:

H2: for countries with a better knowledge-sharing performance, the beneficial impact of digitization on lowering natural resource rents becomes increasingly significant.

**Empirical Methodology**

The following is a presentation of the model used to examine the connection between digitization and environmental performance (EP):

\[ NR_{it} = \beta_0 + \beta_1 DT_{it} + \beta_2 EG_{it} + \beta_3 GEx_{it} + \beta_4 POPU_{it} + \beta_5 FD I_{it} + \beta_6 CAP_{it} + \epsilon_{ijt}, \]

where \( i \) and \( t \) respectively represent country \( i \) and year \( t \), and \( \epsilon_{ijt} \) is the error term.

**Natural Rents**

Ross (2001) claims that resources come in different types, including gold, jewels, petroleum, diamonds, tin, opium, cacao, timbers, and others, but we are forced to choose only four types of natural resource rents: rents from coal, minerals, natural gas, and forests due to the absence of information from reputable organizations like the World Bank about these resource rents for the global sample (collectively referred to as “natural resources rents” or “natural resource rents”). The total of all rentals for these four categories of natural resources is referred to as the total natural resource (NR) rents.
E-Business

- Online retail, e-business, e-commerce sales, and e-commerce web sales, involving the use of customer relationship management (CRM) and the cloud, are all included in the category of “digital business.” We use data from the European Statistics for our digital business analysis (Eurostat). The provided data spans the years 2011 through 2019.

Control Variables

We choose explanatory factors based on the research on natural resource rents (Table 1). We follow Canh et al. (2020) and Phuc Canh and Trung Thong (2020) in examining the impact of income level (EG) as determined by real gross domestic product per capita (USD constant in 2010 $), government expenditures (GEx) as determined by computing the natural logarithm of general government final expenditures per capita, total population (POP), and net inflows of foreign direct investment. GEx’s inclusion in the model illustrates how crucial it is for the government to address market failures (Armey & McNabb, 2018). Foreign direct investment (FDI) and gross capital formation per capita (CAP) are both percentages of GDP. Canh et al. (2021), Ndikumana and Sarr (2019), and Zafar et al. (2019) highlight the considerable implications of FDI on natural resource rents while discussing the function of the FDI. The World Development Indicator provides these factors (WDI). Our database includes 26 nations between 2011 and 2019 after data cleansing. Table 2’s correlation matrix across all variables demonstrates a favorable link between digitalization and natural resource rents.

The subsequent stage of informatics’ step investigates cross-sectional dependency (CD) by using the Pesaran-recommended experiments (2021). Then, to determine if the data are stationary in the presence of CD, we apply the Levin-Lin-Chu unit root test established by Levin et al. (2002) and the Im-Pesaran-Shin unit root test suggested by Im et al. (2003). The outcomes are shown in Table 3. The experiments have shown both the survival of CD and the consistency of the initial various variables. As a result, our model of choice is the panel corrected standard errors (PCSE) one, which is implied by Beck and Katz (1995) and Canh et al. (2020). As shown in Eq. (1), all independent variables are delayed by one period to cope with the endogeneity caused by the concurrent link between digitalization and natural resource rents. We also employ the Feasible Generalized Least Squares (FGLS) model, which, according to Canh et al. (2020), Le and Nguyen (2019), and Liao and Cao, is anticipated to handle the possible problem of heteroscedasticity in Eq. (1) (2013). By doing this, we can guarantee the validity and dependability of the study’s findings.

Another emphasis of this research is the examination of the moderating effect of knowledge-sharing on the link between digitalization and rents from natural resources. To do this, we consider how elements related to digitalization and knowledge-sharing interact. This study uses the economic complexity outlook index (COI), which gauges how simple it is for a nation to diversify its economy,
Table 1 Description of variables

| Variable     | Definition                                                  | Measure                                                                 | Source | Obs | Mean   | SD    | Min | Max  |
|--------------|-------------------------------------------------------------|-------------------------------------------------------------------------|--------|-----|--------|------|-----|------|
| NR           | Natural rents                                              | The share of the sum of coal rents, mineral rents, natural gas rents, and forest rents to GDP (%) | WDI    | 234 | 0.73   | 1.51 | 0.00| 10.97|
| Rent_Coal    | Coal rents                                                 | The share of coal rents to GDP (%)                                      | WDI    | 234 | 0.04   | 0.13 | 0.00| 1.02 |
| Rent_Mineral | Mineral rents                                               | The share of mineral rents to GDP (%)                                   | WDI    | 234 | 0.05   | 0.12 | 0.00| 0.85 |
| Rent_Gas     | Gas rents                                                  | The share of natural gas rents to GDP (%)                               | WDI    | 230 | 0.16   | 0.49 | 0.00| 3.29 |
| Rent_Forest  | Forest rents                                                | The share of forest rents to GDP (%)                                    | WDI    | 234 | 0.18   | 0.26 | 0.00| 1.29 |
| eCOM_Online  | Online selling                                              | The share of individuals selling goods and services online              | Eurostat| 234 | 15.77  | 9.31 | 1.00| 48.00|
| eCOM_Turn    | E-commerce turnover                                         | The share of enterprises with e-commerce sales of at least 1% turnover  | Eurostat| 234 | 16.61  | 7.26 | 3.00| 36.00|
| eCOM_Web     | E-commerce web sales                                        | The share of enterprises with web sales (via websites, apps, or online marketplaces) | Eurostat| 234 | 15.46  | 5.99 | 5.00| 35.00|
| eBUSS_CRP    | CRP                                                         | The share of enterprises with e-commerce, customer relation management (CRM), and secure transaction | Eurostat| 234 | 19.08  | 7.17 | 5.00| 39.00|
| eBUSS_Cloud  | The cloud usage                                             | The share of enterprises using Cloud computing services                | Eurostat| 138 | 26.35  | 15.22| 5.00| 70.00|
| EG           | Real output growth                                          | The real GDP per capital (constant 2010 US dollars)                     | WDI    | 234 | 36.12  | 25.07| 1.02| 111.15|
| GEx          | Government expenditure                                      | The log of general government final consumption expenditure per capita | WDI    | 234 | 24.55  | 1.49 | 22.12| 27.29|
| POPU         | The total population                                        |                                                                         |        |     | 15.86  | 1.24 | 13.16| 18.02|
| FDI          | Net inflow of foreign direct investment                     | The proportion of GDP                                                  | WDI    | 234 | −0.00  | 0.35 | −2.92| 1.63 |
| CAP          | Gross capital formation per capital                         | (Gross capital formation, total)/population                             | WDI    | 234 | 8258.84| 6309.62| 1483.14| 39587.80|

The data used to determine overall digitalization was collected from a number of surveys, including the eGovernment Benchmarking Report, the Eurostat Community survey on ICT usage in households and by individual, and the Eurostat survey on ICT enterprises. WDI, FSSDA, and WBGI all stand for the World Development Indicator and the World Bank Group Indicator, respectively.
Table 2  Correlation coefficients

|       | NR    | eCOM_Online | eCOM_Turn | eCOM_Web | eBUSS_CRP | eBUSS_Cloud | EG     | GEx    | POPU | FDI   | CAP   |
|-------|-------|-------------|-----------|----------|-----------|-------------|--------|--------|------|-------|-------|
| NR    | 1     |             |           |          |           |             |        |        |      |       |       |
| eCOM_Online | 0.350*** | 1             |           |          |           |             |        |        |      |       |       |
| eCOM_Turn  | 0.237**  | 0.534***     | 1         |          |           |             |        |        |      |       |       |
| eCOM_Web   | 0.287*** | 0.597***     | 0.937***  | 1        |           |             |        |        |      |       |       |
| eBUSS_CRP  | 0.225**  | 0.625***     | 0.960***  | 0.979*** | 1         |             |        |        |      |       |       |
| eBUSS_Cloud| 0.228**  | 0.640***     | 0.686***  | 0.741*** | 0.733***  | 1           |        |        |      |       |       |
| EG       | 0.359*** | 0.457***     | 0.436***  | 0.535*** | 0.506***  | 0.540***    | 1      |        |      |       |       |
| GEx      | 0.0405  | 0.395***     | 0.313***  | 0.296*** | 0.337***  | 0.336***    | 0.376*** | 1      |      |       |       |
| POPU     | −0.104  | 0.128        | 0.0453    | −0.0251  | 0.0293    | 0.000865    | −0.0797 | 0.771*** | 1    |       |       |
| FDI      | 0.0589  | 0.0178       | −0.0569   | −0.0440  | −0.0272   | −0.0264     | 0.0514  | −0.0764 | −0.133| 1     |       |
| CAP      | 0.432*** | 0.486***     | 0.589***  | 0.678*** | 0.647***  | 0.591***    | 0.710*** | 0.326*** | −0.093| 0.0148| 1     |

*p < 0.05; **p < 0.01; ***p < 0.001
to determine the degree of economic complexity. The creation of several closely related complicated commodities requiring the same skills or knowledge is indicated by a significant COI. The complexity viewpoint captures the relationship between a country’s present capacity to facilitate simple (or difficult) diversification into interconnected complex production. A low-complexity viewpoint suggests that countries have trouble acquiring new knowledge since there are not many nearby products. The Observatory of Economic Complexity at the MIT Media Lab is where the COI is obtained. The relationship between digitization and the four different forms of resource rents is also examined, the mitigating impacts of knowledge-sharing, as well.

### Empirical Results

#### Baseline Results

The PCSE estimate is used in panel A of Table 4 to show how digitization has affected natural rents. With the exception of “the cloud usage” and “user centricity,” which do not have clinically important impacts on environmental assets rentals, we discover that the other components of commercial strategy and digital general utilities possess a beneficial affect on overall habitual rentals. Particularly, the process

| Variable (in level) | CD test, Pesaran (2004) | Levin-Lin-Chu unit root test | Im-Pesaran-Shin test (Z-bar) | Variable (in difference) | Levin-Lin-Chu unit root test | Im-Pesaran-Shin test (Z-bar) |
|--------------------|-------------------------|----------------------------|----------------------------|--------------------------|-----------------------------|----------------------------|
| NR                 | 36.76***                | −9.55***                   | −3.07***                   | DNR                      | −11.57***                   | −2.13**                    |
| eCOM_Online        | 6.72***                 | −4.03***                   | −0.07                      | DeCOM_Online             | −11.53***                   | −4.84***                   |
| eCOM_Turn          | 20.80***                | −6.46***                   | −2.12**                    | DeCOM_Turn               | −12.32**                    | −4.89***                   |
| eCOM_Web           | 22.21***                | −8.62***                   | −2.42***                   | DeCOM_Web                | −22.17**                    | −5.84***                   |
| eBUSS_CRP          | 19.57***                | −5.88***                   | −1.74**                    | DeBUSS_CRP               | −6.00***                    | −5.42**                    |
| eBUSS_Cloud        | 34.28***                | N/A                        | N/A                        | DeBUSS_Cloud             | N/A                         | N/A                        |
| EG                 | 45.57***                | −5.04***                   | 2.52                       | DEG                      | −9.94***                    | −3.72***                   |
| GEx                | 28.79***                | −0.02                      | 2.93                       | DGEx                     | −9.67***                    | −2.48***                   |
| POPU               | 3.11***                 | −7.30***                   | 3.18                       | DPOPU                    | −13.01***                   | −2.58***                   |
| FDI                | 0.31                    | −7.05***                   | −5.55***                   | DFDI                     | −13.68***                   | −6.03***                   |
| CAP                | 35.78***                | −0.04                      | 3.07                       | DCAP                     | −10.57***                   | −3.78***                   |

The independent cross-section is the null hypothesis for the CD test. The P-value is near to zero, indicating that there is cross-panel correlation in the data. The alternate hypothesis for the Im-Pesaran-Shin test is “At least one panel is stationary,” whereas the null hypothesis is “All panels contain unit root.”
### Table 4  Digitalization and natural rents

**Panel A: PCSE estimates**

| Variables   | NR   | NR   | NR   | NR   | NR   |
|-------------|------|------|------|------|------|
| L.DT        | 0.03*** | 0.03** | 0.07*** | 0.03** | 0.01 |
|             | (0.009) | (0.015) | (0.021) | (0.015) | (0.005) |
| L.EM        | −0.02** | −0.02 | −0.01 | −0.02 | −0.01 |
|             | (0.009) | (0.011) | (0.011) | (0.011) | (0.014) |
| L.GE        | −1.22*** | −1.16*** | −1.34*** | −1.16*** | −1.00*** |
|             | (0.222) | (0.252) | (0.261) | (0.252) | (0.189) |
| L.POPU      | 1.28*** | 1.25*** | 1.45*** | 1.25*** | 1.05*** |
|             | (0.254) | (0.289) | (0.301) | (0.289) | (0.208) |
| L.FDI       | 0.07 | 0.14 | 0.22 | 0.14 | −0.04 |
|             | (0.185) | (0.177) | (0.167) | (0.177) | (0.209) |
| L.CAP       | 0.28*** | 0.26*** | 0.22*** | 0.26*** | 0.22*** |
|             | (0.063) | (0.067) | (0.065) | (0.067) | (0.062) |

Observations | 208 | 208 | 208 | 208 | 112 |
R-squared     | 0.352 | 0.335 | 0.365 | 0.335 | 0.332 |
Number of countries | 26 | 26 | 26 | 26 | 26 |

**Panel B: FGLS**

| Variables   | NR   | NR   | NR   | NR   | NR   |
|-------------|------|------|------|------|------|
| L.DT        | 0.03*** | 0.03** | 0.07*** | 0.03** | 0.01 |
|             | (0.011) | (0.017) | (0.020) | (0.017) | (0.011) |
| L.EM        | −0.02* | −0.02 | −0.01 | −0.02 | −0.01 |
|             | (0.011) | (0.013) | (0.012) | (0.013) | (0.015) |
| L.GE        | −1.22*** | −1.16*** | −1.34*** | −1.16*** | −1.00*** |
|             | (0.287) | (0.303) | (0.290) | (0.303) | (0.409) |
| L.POPU      | 1.28*** | 1.25*** | 1.45*** | 1.25*** | 1.05*** |
|             | (0.323) | (0.342) | (0.330) | (0.342) | (0.462) |
| L.FDI       | 0.07 | 0.14 | 0.22 | 0.14 | −0.04 |
|             | (0.223) | (0.229) | (0.224) | (0.229) | (0.280) |
| L.CAP       | 0.28*** | 0.26*** | 0.22*** | 0.26*** | 0.22*** |
|             | (0.039) | (0.045) | (0.044) | (0.045) | (0.049) |

Observations | 208 | 208 | 208 | 208 | 112 |
Number of countries | 26 | 26 | 26 | 26 | 26 |

Standard errors in parentheses

*p < 0.1; **p < 0.05; ***p < 0.01
of numerical transformation in the private and public sectors raises the rentals on natural resources. The literature also reveals a similar discovery on this connection. For instance, research by Sadorsky (2012), Salahuddin and Alam (2016), Longo and York (2015) shows that digitalization increases energy use, whereas energy use causes pollution emissions (Can & Gozgor, 2017). By encouraging technological and trade-related R&D spillover effects (Basu & Fernald, 2007; Ceccobelli et al., 2012; Dunnewijk & Hultén, 2007), the development of digital commerce and different knowledge and connectivity technologies might also amplify those effects, hastening the spread of green technologies across industries and nations.

Regarding the regulating variables, the results show that rising population and gross capital formation per capita have a favorable effect on natural rents. On the other hand, rising real production growth and government spending contribute to a decrease in natural rents. It suggests that those are essential criteria for nations to lessen natural rent-seeking. The FGLS model is used to verify the validity of our conclusions, and the results are shown in panel B. The outcomes are comparatively similar to those shown in panel A of Table 4, indicating that there is a reason for us to believe what we have discovered.

To provide insight on how digitalization and natural resource rents interact, we reevaluate this relationship by utilizing a variety of resources in nature, involving minerals, forest, coal, and natural gas. According to Conigliani et al. (2018) and Zheng et al. (2018), these kinds of natural resources react to outside changes like digitization in distinct ways. So, we take into account how the digitization of society has affected the rents of these four natural resources. First off, the beneficial effects of commerce on coal rents are illustrated by that influence, which is shown in panel A.

In contrast, out of the five components of a digital firm, two—online selling and cloud—have a favorable impact on mining rentals, while the other three (e-commerce turnover, e-commerce web sales, and CRP) have a negative impact. Panels C and D show how digitization has affected rents from gas and forests. The findings demonstrate that growing the scope of digital public infrastructure leads to a greater reliance on them. Digitalization is not the same as how they have changed. For instance, as firms adopt digital transformation, their reliance on gas resources also rises, but the three aspects (e-commerce turnover, e-commerce web sales, and CRP) of digital business that have a detrimental effect on forest rentals also have a similar detrimental influence on mineral rents.

**Moderating Role of Knowledge-Sharing**

The fact that this research emphasizes the significance of knowledge-sharing in modifying the link between digitalization and natural resource rents is one of its most significant contributions. Table 6 provides a summary of this analyses’ findings. The link between knowledge-sharing and digitalization, as indicated by the
| VARIABLES         | (1)     | (2)     | (3)     | (4)     | (5)     |
|-------------------|---------|---------|---------|---------|---------|
| L.DT              | 0.11*** | 0.04    | 0.10*** | 0.04    | 0.03**  |
|                  | (0.025) | (0.024) | (0.037) | (0.024) | (0.017) |
| L.ECI             | 1.05*** | 1.35*** | 1.48*** | 1.35*** | 1.28*** |
|                  | (0.164) | (0.285) | (0.316) | (0.285) | (0.335) |
| L.ECI*DT          | -0.08***| -0.07***| -0.10***| -0.07***| -0.05***|
|                  | (0.017) | (0.018) | (0.025) | (0.018) | (0.016) |
| L.EG              | 0.04*** | 0.03**  | 0.02**  | 0.03**  | 0.02    |
|                  | (0.011) | (0.012) | (0.011) | (0.012) | (0.014) |
| L.GE              | -1.48***| -0.97***| -0.96***| -0.97***| -0.40   |
|                  | (0.264) | (0.315) | (0.287) | (0.315) | (0.320) |
| L.POPU            | 1.30*** | 0.84**  | 0.87*** | 0.84**  | 0.19    |
|                  | (0.283) | (0.347) | (0.317) | (0.347) | (0.355) |
| L.FDI             | 0.14    | 0.09    | 0.20    | 0.09    | -0.09   |
|                  | (0.143) | (0.140) | (0.156) | (0.140) | (0.140) |
| L.CAP             | 0.11    | 0.16**  | 0.12    | 0.16**  | 0.11    |
|                  | (0.070) | (0.079) | (0.076) | (0.079) | (0.076) |
| Observations      | 200     | 200     | 200     | 200     | 109     |
| Number of countries| 25      | 25      | 25      | 25      | 25      |
| Panel A: PCSE model | (1) | (2) | (3) | (4) | (5) |
|---------------------|-----|-----|-----|-----|-----|
| Digital Business    |     |     |     |     |     |
| e-Commerce: Online Selling |     |     |     |     |     |
| Variables NR        |     |     |     |     |     |
| Panel B: FGLS model | (1) | (2) | (3) | (4) | (5) |
| Digital Business    |     |     |     |     |     |
| e-Commerce: Online Selling |     |     |     |     |     |
| Variables L.DT      | 0.11*** | 0.04* | 0.10*** | 0.04* | 0.03* |
|                     | (0.018) | (0.022) | (0.027) | (0.022) | (0.017) |
| Variables L.ECI     | 1.05*** | 1.35*** | 1.48*** | 1.35*** | 1.28*** |
|                     | (0.204) | (0.391) | (0.353) | (0.391) | (0.367) |
| Variables L.ECI*DT  | -0.08*** | -0.07*** | -0.10*** | -0.07*** | -0.05*** |
|                     | (0.015) | (0.021) | (0.025) | (0.021) | (0.015) |
| Variables L.EG      | 0.04*** | 0.03* | 0.02* | 0.03* | 0.02 |
|                     | (0.013) | (0.014) | (0.013) | (0.014) | (0.016) |
| Variables L.GE      | -1.48*** | -0.97*** | -0.96*** | -0.97*** | -0.40 |
|                     | (0.274) | (0.340) | (0.329) | (0.340) | (0.433) |
| Variables L.POPU    | 1.30*** | 0.84** | 0.87** | 0.84** | 0.19 |
|                     | (0.300) | (0.370) | (0.357) | (0.370) | (0.485) |
| VARIABLES | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| **L.FDI** | 0.14 | 0.09 | 0.20 | 0.09 | -0.09 |
|           | (0.233) | (0.250) | (0.247) | (0.250) | (0.255) |
| **L.CAP** | 0.11*** | 0.16*** | 0.12*** | 0.16*** | 0.11*** |
|           | (0.040) | (0.045) | (0.044) | (0.045) | (0.049) |
| Observations | 200 | 200 | 200 | 200 | 109 |
| Number of countries | 25 | 25 | 25 | 25 | 25 |

Standard errors in parentheses

*p<0.01, **p<0.05, ***p<0.1
Table 7 Moderating roles of knowledge-sharing on the link between digitalization and various types of natural resource rents

Panel A: coal rents

| Variables          | 1      | 2      | 3      | 4      | 5      |
|--------------------|--------|--------|--------|--------|--------|
| L.DT               | 0.00   | 0.01***| 0.01***| 0.01***| −0.00  |
|                    | (0.000)| (0.001)| (0.002)| (0.001)| (0.001)|
| L.ECI              | −0.03***| 0.06***| 0.03***| 0.06***| −0.04***|
|                    | (0.005)| (0.015)| (0.013)| (0.015)| (0.011)|
| L.ECI*DT           | 0.00***| −0.00***| −0.00***| −0.00***| −0.00***|
|                    | (0.000)| (0.001)| (0.001)| (0.001)| (0.001)|
| L.LEG              | 0.00***| 0.00***| 0.00***| 0.00***| 0.00***|
|                    | (0.000)| (0.000)| (0.000)| (0.000)| (0.000)|
| L.GE               | −0.12***| −0.08***| −0.09***| −0.08***| −0.11***|
|                    | (0.020)| (0.013)| (0.013)| (0.013)| (0.010)|
| L.POPU             | 0.15***| 0.11***| 0.12***| 0.11***| 0.14***|
|                    | (0.024)| (0.017)| (0.017)| (0.017)| (0.012)|
| L.FDI              | 0.00   | 0.02   | 0.01   | 0.02   | 0.01   |
|                    | (0.009)| (0.011)| (0.011)| (0.011)| (0.007)|
| L.CAP              | 0.00***| −0.00  | −0.00  | −0.00  | 0.00** |
|                    | (0.001)| (0.001)| (0.001)| (0.001)| (0.002)|
| Observations       | 200    | 200    | 200    | 200    | 109    |
| R-squared          | 0.395  | 0.445  | 0.410  | 0.445  | 0.455  |
| Number of countries| 25     | 25     | 25     | 25     | 25     |

Panel B: mineral rents

| Variables          | 1      | 2      | 3      | 4      | 5      |
|--------------------|--------|--------|--------|--------|--------|
| L.DT               | −0.00  | 0.00   | −0.00  | 0.00   | 0.00** |
|                    | (0.001)| (0.001)| (0.001)| (0.001)| (0.001)|
| L.ECI              | 0.01   | 0.10***| 0.07***| 0.10***| 0.01   |
|                    | (0.009)| (0.023)| (0.018)| (0.023)| (0.016)|
| L.ECI*DT           | 0.00   | −0.00***| −0.00***| −0.00***| −0.00  |
|                    | (0.001)| (0.001)| (0.001)| (0.001)| (0.001)|
| L.LEG              | 0.00***| 0.00***| 0.00***| 0.00***| 0.00***|
|                    | (0.001)| (0.001)| (0.001)| (0.001)| (0.001)|
| L.GE               | −0.18***| −0.13***| −0.14***| −0.13***| −0.16***|
|                    | (0.038)| (0.034)| (0.036)| (0.034)| (0.029)|
| L.POPU             | 0.21***| 0.15***| 0.17***| 0.15***| 0.19***|
|                    | (0.042)| (0.037)| (0.039)| (0.037)| (0.032)|
| L.FDI              | 0.01   | 0.01   | 0.01   | 0.01   | 0.02** |
|                    | (0.009)| (0.009)| (0.009)| (0.009)| (0.010)|
### Table 7 (continued)

#### Panel A: coal rents

| Variables | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| L.CAP     | 0.01*** | 0.00*** | 0.00*** | 0.00*** | 0.00 |
| L.DT      | 0.01*** | 0.01** | 0.04*** | 0.01** | 0.01 |
| L.ECI     | 0.29*** | 0.32*** | 0.39*** | 0.32*** | 0.39*** |
| L.ECI*DT  | −0.02*** | −0.01** | −0.03*** | −0.01** | −0.02*** |
| L.EM       | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.01*** |
| L.GE      | −0.55*** | −0.46*** | −0.44*** | −0.46*** | −0.22*** |
| L.POPU    | 0.52*** | 0.45*** | 0.45*** | 0.45*** | 0.18** |
| L.FDI     | 0.13* | 0.12** | 0.16** | 0.12** | 0.02 |
| L.CAP     | 0.03 | 0.04* | 0.02 | 0.04* | 0.04 |

#### Panel C: gas rents

| Variables | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| L.DT      | 0.03*** | 0.01** | 0.04*** | 0.01** | 0.01 |
| L.ECI     | 0.29*** | 0.32*** | 0.39*** | 0.32*** | 0.39*** |
| L.ECI*DT  | −0.02*** | −0.01** | −0.03*** | −0.01** | −0.02*** |
| L.EM       | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.01*** |
| L.GE      | −0.55*** | −0.46*** | −0.44*** | −0.46*** | −0.22*** |
| L.POPU    | 0.52*** | 0.45*** | 0.45*** | 0.45*** | 0.18** |
| L.FDI     | 0.13* | 0.12** | 0.16** | 0.12** | 0.02 |
| L.CAP     | 0.03 | 0.04* | 0.02 | 0.04* | 0.04 |

#### Panel D: forest rents

| Variables | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| L.DT      | 0.01*** | −0.00*** | −0.01*** | −0.00*** | 0.01*** |
| L.ECI     | 0.08*** | 0.18*** | 0.12*** | 0.18*** | 0.16*** |
| L.ECI*DT  | −0.00** | −0.01*** | −0.00** | −0.01*** | −0.00*** |
| L.EM       | −0.01*** | −0.02*** | −0.02*** | −0.02*** | −0.01*** |

- NR: Not reported
- Coefficients: 0.01***, 0.00***, etc. indicate statistical significance at the 1%, 0.1%, etc. level.
COI, is economically important and negative, as shown in panel A, demonstrating how the latter negatively affects the former. In other words, countries with high financial problems (i.e., an increase of information that showed up in a nation’s manufacturing systems) are a crucial factor in ensuring that digitization, in the private as well as general sectors, is successful in reducing rents on environmental assets at the national level. The findings are extremely significant because they demonstrate that the digital transition needed to reduce reliance on natural resources cannot be deceived and must instead be undertaken in nations with superior quality and a more diverse production system. The necessity of assuring the success of a new strategy or element in lowering reliance on natural resources provides instances of the relevance of economic complexity in addition to the effects that it has directly on the rents from natural resources, as indicated by Canh et al. (2020). The positive impacts might be to blame for this of web technologies on financial development and personnel resources, which underpins R&D efforts and technical advancement progress (Ferro, 2011; Haini, 2019; Salahuddin & Gow, 2016; Spiezia, 2011). As a result, as technology advances, industrial structures become less source of energy. This enables the development of further eco-friendly methods and the displacement of low-energy technology with high-energy technology (Airehrour et al., 2016; Li et al., 2019; Ren et al., 2021). Similar to the prior research, we employ several analytical techniques to verify the reliability of the findings over the range of estimations as shown

| Variables | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| L.GE | 0.02 | 0.13*** | 0.10** | 0.13*** | 0.04 |
| L.POPU | −0.11*** | −0.24*** | −0.21*** | −0.24*** | −0.14*** |
| L.FDI | −0.01 | −0.03 | −0.03 | −0.03 | −0.03* |
| L.CAP | 0.03*** | 0.04*** | 0.04*** | 0.04*** | 0.02*** |
| Observations | 200 | 200 | 200 | 200 | 109 |
| R-squared | 0.496 | 0.520 | 0.519 | 0.520 | 0.450 |
| Number of countries | 25 | 25 | 25 | 25 | 25 |

Standard errors in parentheses

*p < 0.1; **p < 0.05; ***p < 0.01
in panel B. As a result, this remark makes a significant literary contribution. It means that the essential factor for the digital economy’s attempt to avoid inherent rent-seeking is economic complexity or the standard and range of the production process. The outcomes are displayed in Table 7’s panels A through D. Next, we investigate how the connection between technology and the rents of four different kinds of environmental assets is moderated by economic complexity, involving power resources. The success of digitization in achieving a decrease still heavily depends on how complicated the economy is in nations’ dependence on natural resources, even though the commercial and public sectors’ digitalization has a varied impact on rents of these four natural resources.

Conclusions

The connection between technological development and natural rents has never been scientifically examined before by anyone. We provide important findings utilizing the global dataset of 26 European nations. First, the research looked at how digitization affected natural rents and their constituent parts. We wish to underline how favorably total natural rents are impacted by digital companies and digital public services. Additionally, the effect of digital enterprises on rents of oil and petroleum is growing, whereas the rising scale of electronic utilities results in a stronger dependency on mining, gasoline, and woodland rentals. Digital enterprises, on the other hand, tend to lower mineral and forest rentals, while digital public utilities tend to lower mining rentals. More important is the decline in total natural rents for countries with significant quantitative methodology (Table 8).

Our long-term policy research indicates that the growth of digitalization leads to a reduction in the natural resource usage. Therefore, continued investments in digitalization across all factors are necessary to preserve the environmental assets’ protection. The COVID-19 crisis’s emerging digital transformation trend and how it permanently changed corporate and government management practices suggest that overall natural resource security is improving. Additionally, these nations must adopt crucial strategies to lessen the strain on the security of their energy and natural resource supplies, hastening the adoption of technologies for greater usage of less power and integrating stronger natural norms and regulations into the development agenda, among other things. Thus, increasing economic complexity offers a tremendous opportunity to enhance energy security.
Appendix

Table 8

| EU countries |
|--------------|
| Austria      | Hungary    | Portugal |
| Belgium      | Iceland    | Slovak Republic |
| Bulgaria     | Ireland    | Slovenia |
| Czech Republic | Italy    | Sweden |
| Denmark      | Lithuania  |          |
| Spain        | Luxembourg |          |
| Estonia      | Latvia     |          |
| UK           | Malta      |          |
| Greece       | Netherlands|          |
| Croatia      | Poland     |          |

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Declarations

Ethics Approval  There is no human participant in this paper.

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References

Airehrour, D., Gutiérrez, J., & Ray, S. K. (2016). Greening and optimizing energy consumption of sensor nodes in the Internet of Things through energy harvesting: Challenges and approaches. International Conference on Information Resources Management (Conf-IRM 2016), Cape Town, South Africa.

Antonelli, C. (2011). Handbook on the economic complexity of technological change [Books]. Edward Elgar Publishing. https://econpapers.repec.org/bookchap/elgeebook/13391.htm

Armey, L., & McNabb, R. M. (2018). Expenditure decentralization and natural resources. https://calhoun.nps.edu/handle/10945/66807
Autio, E., Nambisan, S., Thomas, L. D. W., & Wright, M. (2018). Digital affordances, spatial affordances, and the genesis of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal, 12*(1), 72–95. https://doi.org/10.1002/sej.1266

Barber, L. K., & Santuzzi, A. M. (2015). Please respond ASAP: Workplace telepressure and employee recovery. *Journal of Occupational Health Psychology, 20*(2), 172–189. https://doi.org/10.1037/0a0038278

Basu, S., & Fernald, J. (2007). Information and communications technology as a general-purpose technology: Evidence from US industry data. *German Economic Review, 8*(2), 146–173. https://doi.org/10.1111/j.1468-0475.2007.00402.x

Beck, N., & Katz, J. N. (1995). What to do (and not to do) with time-series cross-section data. *The American Political Science Review, 89*(3), 634–647. https://doi.org/10.2307/2082979

Bernstein, R., & Madlener, R. (2010). Impact of disaggregated ICT capital on electricity intensity in European manufacturing. *Applied Economics Letters, 17*(17), 1691–1695. https://doi.org/10.1080/13504850903120717

Bouncken, R., & Barwinski, R. (2021). Shared digital identity and rich knowledge ties in global 3D printing—A drizzle in the clouds? *Global Strategy Journal, 11*(1), 81–108. https://doi.org/10.1002/gsj.1370

Can, M., & Gozgor, G. (2017). The impact of economic complexity on carbon emissions: Evidence from France. *Environmental Science and Pollution Research, 24*(19), 16364–16370. https://doi.org/10.1007/s11356-017-9219-7

Canh, N. P., Schinckus, C., & Thanh, S. D. (2020). The natural resources rents: Is economic complexity a solution for resource curse? *Resources Policy, 69*, 101800. https://doi.org/10.1016/j.resourpol.2020.101800

Canh, N. P., Schinckus, C., Thanh, S. D., & Chong, F. H. L. (2021). The determinants of the energy consumption: A shadow economy-based perspective. *Energy, 225*, 120210.

Ceccobelli, M., Gitto, S., & Mancuso, P. (2012). ICT capital and labour productivity growth: A non-parametric analysis of 14 OECD countries. *Telecommunications Policy, 36*(4), 282–292. https://doi.org/10.1016/j.telpol.2011.12.012

Chou, Y.-C., Hao-Chun Chuang, H., & Shao, B. B. M. (2014). The impacts of information technology on total factor productivity: A look at externalities and innovations. *International Journal of Production Economics, 158*, 290–299. https://doi.org/10.1016/j.ijpe.2014.08.003

Collard, F., Fève, P., & Portier, F. (2005). Electricity consumption and ICT in the French service sector. *Energy Economics, 27*(3), 541–550. https://doi.org/10.1016/j.eneco.2004.12.002

Conigliani, C., Cuffaro, N., & D’Agostino, G. (2018). Large-scale land investments and forests in Africa. *Land Use Policy, 75*, 651–660. https://doi.org/10.1016/j.landusepol.2018.02.005

Devold, H., Graven, T., & Halvorsrød, S. O. (2017). Digitization of oil and gas facilities reduce cost and improve maintenance operations. *Offshore Technology Conference*. https://doi.org/10.4043/27788-MS

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics, 49*(4), 431–455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Dunnewijk, T., & Hultén, S. (2007). A brief history of mobile communication in Europe. *Telematics and Informatics, 24*(3), 164–179. https://doi.org/10.1016/j.tele.2007.01.013

EDPR. (2017). Shaping Europe’s digital future. (n.d.). Retrieved June 17, 2022, from https://digital-strategy.ec.europa.eu/en/library/europes-digital-progress-report-2017

European Commission. (1999). *The EU’s eco-industry’s export potential*. Final report to DGXI of the European Commission.

European Environment Agency. (2020a). *Natural resources and waste — European Environment Agency*. (n.d.). [Page]. Retrieved October 17, 2021, from https://www.eea.europa.eu/soer/2010/synthesis/synthesis/chapter4.xhtml

European Environment Agency. (2020b). Europe’s state of the environment 2020b: Change of direction urgently needed to face climate change challenges, reverse degradation and ensure future prosperity. [News]. Retrieved October 17, 2021, from https://www.eea.europa.eu/highlights/soer2020b-europes-environment-state-and-outlook-report

Faisal, F., Tursoy, T., & Berk, N. (2018). Linear and non-linear impact of Internet usage and financial deepening on electricity consumption for Turkey: Empirical evidence from asymmetric causality. *Environmental Science and Pollution Research, 25*(12), 11536–11555. https://doi.org/10.1007/s11356-018-1341-7
Madlener, R., & Sunak, Y. (2011). Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? *Sustainable Cities and Society*, 1(1), 45–53. https://doi.org/10.1016/j.scs.2010.08.006

Martínez-Zarzoso, I., & Maruotti, A. (2011). The impact of urbanization on CO2 emissions: Evidence from developing countries. *Ecological Economics*, 70(7), 1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009

Moyer, J. D., & Hughes, B. B. (2012). ICTs: Do they contribute to increased carbon emissions? *Technological Forecasting and Social Change*, 79(5), 919–931. https://doi.org/10.1016/j.techfore.2011.12.00

Ndikumana, L., & Sarr, M. (2019). Capital flight, foreign direct investment and natural resources in Africa. *Resources Policy*, 63, 101427. https://doi.org/10.1016/j.resourpol.2019.101427

Owusu-Agyei, S., Okafor, G., Chijoke-Mgbame, A. M., Ohalehi, P., & Hasan, F. (2020). Internet adoption and financial development in sub-Saharan Africa. *Technological Forecasting and Social Change*, 161, 120293. https://doi.org/10.1016/j.techfore.2020.1202

Pesaran, M. H. (2004). General Diagnostic Tests for Cross Section Dependence in Panels [SSRN Scholarly Paper]. https://doi.org/10.2139/ssrn.572504

Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical Economics*, 60(1), 13–50. https://doi.org/10.1007/s00181-020-01875-7

Phuc Canh, N., & Trung Thong, N. (2020). Nexus between financialisation and natural resources rents: Empirical evidence in a global sample. *Resources Policy*, 66, 101590. https://doi.org/10.1016/j.resourpol.2020.101590

Pop, L. D. (2020). Digitalization of the system of data analysis and collection in an automotive company. *Procedia Manufacturing*, 46, 238–243. https://doi.org/10.1016/j.promfg.2020.03.035

Porter, M. E., & Heppelmann, J. E. (2015, October 1). How Smart, Connected Products Are Transforming Companies. Harvard Business Review. https://hbr.org/2015/10/how-smart-connected-products-are-transformingcompanies

Qin, J., Liu, Y., & Grosvenor, R. (2017). Data analytics for energy consumption of digital manufacturing systems using Internet of Things method. 2017 13th IEEE Conference on Automation Science and Engineering (CASE). https://doi.org/10.1109/coase.2017.8256150

Ren, S., Hao, Y., Xu, L., Wu, H., & Ba, N. (2021). Digitalization and energy: How does internet development affect China’s energy consumption? *Energy Economics*, 98(98), 1–20. https://doi.org/10.1016/j.eneco.2021.105220

Ribeiro-Navarrete, S., Botella-Carrubi, D., Palacios-Marqués, D., & Orero-Blat, M. (2021). The effect of digitalization on business performance: An applied study of KIBS. *Journal of Business Research*, 126, 319–326. https://doi.org/10.1016/j.jbusres.2020.12.065

Ross, M., 2001. How Does Natural Resource Wealth Influence Civil War? University of California at Los Angeles Political Science Department, Los Angeles (Available online at: http://www.eireview.org/. Processed).

Sadorsky, P. (2012). Energy consumption, output and trade in South America. *Energy Economics*, 34(2), 476–488. https://doi.org/10.1016/j.eneco.2011.12.008

Salahuddin, M., & Alam, K. (2016). Information and communication technology, electricity consumption and economic growth in OECD countries: A panel data analysis. *International Journal of Electrical Power & Energy Systems*, 76, 185–193. https://doi.org/10.1016/j.ijepes.2015.11.005

Salahuddin, M., & Gow, J. (2016). The effects of Internet usage, financial development and trade openness on economic growth in South Africa: A time series analysis. *Telematics and Informatics*, 33(4), 1141–1154. https://doi.org/10.1016/j.tele.2015.11.006

Salahuddin, M., Gow, J., & Ozturk, I. (2015). Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust? *Renewable & Sustainable Energy Reviews*, 51, 317–326.

Schmener, R. W. (2004). Service Businesses and Productivity. *Decision Sciences*, 35(3), 333–347. https://doi.org/10.1111/j.0011-7315.2004.02558.x

Shujahat, M., Ali, B., Nawaz, F., Durst, S., & Kianto, A. (2018). Translating the impact of knowledge management into knowledge-based innovation: The neglected and mediating role of knowledge-worker satisfaction. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 28(4), 200–212. https://doi.org/10.1002/hfm.20735

Shujahat, M., Sousa, M. J., Hussain, S., Nawaz, F., Wang, M., & Umer, M. (2019). Translating the impact of knowledge management processes into knowledge-based innovation: The neglected and mediating role of knowledge-worker productivity. *Journal of Business Research*, 94, 442–450. https://doi.org/10.1016/j.jbusres.2017.11.001
Sinclair-Desgagné, B. (2008). The environmental goods and services industry. *International Review of Environmental and Resource Economics*, 2(1), 69–99.

Solomon, E. M., & van Klyton, A. (2020). The impact of digital technology usage on economic growth in Africa. *Utilities Policy*, 67, 101104. https://doi.org/10.1016/j.jup.2020.101104

Sorrell, S. (2007). The rebound effect: An assessment of the evidence for economywide energy savings from improved energy efficiency. UK Energy Research Centre.

Spiezia, V. (2011). Are ICT users more innovative?: An Analysis of ICT-enabled innovation in OECD firms. *OECD Journal: Economic Studies*, 2011(1). https://doi.org/10.1787/eco_studies-2011-5kg2d2hkn6vg

Stern, D. I. (2004). Environmental Kuznets curve. In *Encyclopedia of Energy* (pp. 517–525). https://doi.org/10.1016/b0-12-176480-x/00454-x29

Takase, K., & Murota, Y. (2004). The impact of IT investment on energy: Japan and US comparison in 2010. *Energy Policy*, 32(11), 1291–1301. https://doi.org/10.1016/s0301-4215(03)00097-1

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy*, 37(1), 246–253. https://doi.org/10.1016/j.enpol.2008.08.025

UN (2019). THE 17 GOALS | Sustainable Development. (n.d.). Retrieved April 10, 2022, from https://sdgs.un.org/goals

Vassileva, I., Wallin, F., & Dahlquist, E. (2012). Understanding energy consumption behavior for future demand response strategy development. *Energy*, 46(1), 94–100. https://doi.org/10.1016/j.energy.2012.02.069

Verma, P., Savickas, R., Buettner, S.M., Striker, J., Kjeldsen, O., & Wang, X. (2020). *Digitalization: Enabling the new phase of energy efficiency. Regulatory and policy dialogue addressing barriers to improve energy efficiency, 7th session, Geneva*. Available from https://unep.org/sites/default/files/2020-12/GEEE-7.2020.INF_.3.pdf. Retrieved 18 August 2021.

Vuori, V., Helander, N., & Okkonen, J. (2019). Digitalization in knowledge work: The dream of enhanced performance. *Cognition, Technology & Work*, 21(2), 237–252. https://doi.org/10.1007/s10111-018-0501-3

Woods, D. D., Patterson, E. S., & Roth, E. M. (2002). Can We Ever Escape from Data Overload? A Cognitive Systems Diagnosis. *Cognition, Technology & Work*, 4(1), 22–36. https://doi.org/10.1007/s10111-018-0500-4

World Economic Forum (2021). The Global Risks Report 2021. Retrieved November 20, 2021, from https://www.weforum.org/reports/the-global-risks-report-2021/

Wu, F., Huberman, B. A., Adamic, L. A., & Tyler, J. R. (2004). Information flow in social groups. *Physica A: Statistical Mechanics and Its Applications*, 337(1), 327–335. https://doi.org/10.1016/j.physa.2004.01.030

Yang, L., & Li, Z. (2017). Technology advance and the carbon dioxide emission in China – Empirical research based on the rebound effect. *Energy Policy*, 101, 150–161. https://doi.org/10.1016/j.enpol.2016.11.020. Statements & Declarations.

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. *Resources Policy*, 63, 101428. https://doi.org/10.1016/j.resourpol.2019.101428

Zheng, M., Li, J., Wu, X., Wang, S., Guo, Q., Yu, J., Zheng, M., Chen, N., & Yi, Q. (2018). China’s conventional and unconventional natural gas resources: Potential and exploration targets. *Journal of Natural Gas Geoscience*, 3(6), 295–309. https://doi.org/10.1016/j.jnggs.2018.11.007

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