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Article

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Effects of Digitalization on Natural Resource Use in European Countries: Does Economic Complexity Matter?

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ABSTRACT

This paper empirically analyses the influences of the digital transformation process in the business and public sector on natural resources rents. Our paper employs the digital businesses (e-Commerce, including the value of online selling, e-Commerce turnover, e-Commerce web sales, and e-Business, including customer relationship management (CRM) usage and cloud usage) and the digital public services (user-centricity, business mobility, and key enablers), while we deal with the total natural rents (coal rents, mineral rents, natural gas rents, and forest rents). The various econometric techniques are applied to a sample of 26 European Union countries during the 2011–2019 period. Our estimation results demonstrate that both digital businesses and digital public services lead to a rise in total natural rents. More specifically, the digital businesses appear to have increased influences on coal rents, and gas rents, while the digital public services drive mineral rents, gas rents, and forest rents up. Conversely, digital public services tend to reduce coal rents and digital businesses lead to a decrease in mineral rents and forest rents. Notably, the economic complexity or the quality and diversification of the production system is the key variable for the digital economy aiming at shirking natural rent-seeking. The findings are consistent when we consider the specific type of natural resource rent regardless of whether they are affected differently by digital transformation.

Keywords: Digital Business, Digital Public Services, Natural Rents, Economic Complexity, European Countries
JEL Classifications: F21, G21, O16, C33

1. INTRODUCTION

Among 17 goals proposed by the United Nations to achieve sustainable development, sustainable consumption and production are some of the most crucial goals. In the process of conducting economic and production activities, humans are extracting and processing materials and natural resources excessively while ignoring or slowly implementing the process of economical and efficient resource consumption. Some of the world's major resource-intensive countries are Kuwait, Colombia, and Russia ranked based on the ratio of total natural resources to GDP (%). In contrast, advanced countries such as Australia, Finland, France, Germany, Hong Kong, Italy, Japan, and New Zealand have relatively low rates of natural resource rents (Canh et al., 2020).

The rents of natural resources are complicated by many different trends in worldwide areas. For instance, some countries like Canada, China, the Philippines, Russia appear to have a decreasing trend, whilst there is a sign of an increasing trend in Cambodia, Vietnam. The natural resource curse issue is gradually becoming a more and more important issue that requires more specialized investigations in various dimensions and different regions, especially in the European area where the environmental impacts of resource use become increasingly severe (The European Environment Outlook, 2020a). In Europe, when resource use exceeds local availability[1], countries become dependent and competitive for resources from other countries, which comes to questions about security in the supply of resources for the European region in the long run and exists a potential for future conflicts (The European Environment Outlook, 2020a). According to a warning of the European Environment Outlook (2020b), Europe will not attain its 2030 goals if this region does not adopt an urgent action during the next 10 years to deal with the alarming rate of biodiversity loss, rising influences of climate change, and the overconsumption of natural resources.

There is an increasing number of papers that study the problems of the natural resources curse. Emerging literature has indicated the importance of digitalization in changing the production way, and then enhancing economic growth. According to Autio et al. (2018), digitalization can be defined as the process of applying digital technologies and infrastructures in diverse aspects of businesses, the economy, and society. Many individuals nowadays are familiar with the use of information technology in production and business. Every element of the economy has been progressively digitized as the industrial revolution progressed. Digitization provides a driving force for the industry to evolve more quickly because it can quickly reduce numerous labor and products intermediate costs (Devold et al., 2017; Herzog et al., 2017; Pop, 2020) and help cross-border firms trade more straightforwardly, thus giving them new investment options (Damgaard et al., 2018). The digital information system also enables foreign businesses to expand their reach into new markets (World Economic Forum, 2021). Moreover, as a crucial driver of economic prosperity by fostering financial and economic globalization (Farhadi et al., 2012; Solomon and van Klyton, 2020), digitalization may also enhance the needs for well-being and environmental awareness (Lee and Lee, 2009; Martínez-Zarzoso and Maruotti, 2011). In this regard, digitalization would not only encourage green consumption among consumers but also urge firms to implement cleaner production and invest in green innovation as a response to competitive pressures and environmental regulations (European Commission, 1999; International Trade Centre, 2001; Kennett and Steenblik, 2005; Sinclair-Desgagné, 2008). As a result, digitalization may play a critical role in influencing natural resources rents. However, the association between the digitalization and natural resources rents has still been kept silent in the literature thus far.

Furthermore, Canh et al. (2020) reveal that the structural changes in the economic systems appear to have a significant influence on natural rents. The complexity of the economies (economic complexity) reflects the changes in productions. The prior scholars, such as Hidalgo and Hausmann (2009), Hausmann and Hidalgo (2014) employ the Economic Complexity Index to quantify the amount of knowledge materialized in the production systems of countries. The detailed discussions argued by Antonelli (2011) reveal the link between economic complexity and technology and innovation adoption. In this paper, we believe that the economic complexity builds a capacity for the deployment of the digital revolution, which accelerates the effects of digitalization on natural resources rents.

In line with the rest of the world, the goal of the EU is to turn into the digital economy, which integrates high technology, the development of artificial intelligence, and so on into different fields of the economy. Europe's Digital Progress Report (EDPR) for EU countries (EDPR, 2017) indicates a significant difference in the integration of digital technology. Based on a digital economy and society index (DESI) calculated from connectivity, digital skills, internet use and the use of digital technology in the business and public sector, Romania and Bulgaria had the lowest score, while Scandinavian countries and other smaller countries were at the top. Almost all countries have to concentrate on developing a national Digital Agenda or Digital Strategy. Many initiatives in digitization of industry and public services, investment in digital infrastructure and services, research programs, cybersecurity, e-commerce, copyright, and data protection legislation were launched during the period 2014–2019. According to the EDPR (2017), the DESI of the EU increased substantially from 0.43 in 2014 to 0.52 in 2019. Roughly 99% of the EU households were covered by basic fixed broadband. There was a gradual increase in the level, which small and medium size EU enterprises (SMEs) integrated digital technology into their business. In digital public services, the percentage of internet users that have exchanged forms with the public administration online is 38%. In general, the process of digital transformation is considered to be taking place strongly in Europe during the 2012–2019 period.

Our study makes at least two contributions to the literature. First, this study is the first attempt to examine the impacts of the process of digital transformation on the natural rents in the European region. By using various indicators to capture the digital transformation process in both the business and public sector, this paper is expected to provide a more comprehensive analysis on the link between digitalization and natural resources rents. Second, our paper also indicates the importance of economic complexity in influencing the impacts of digitalization on natural rents. While previous studies highlight the economic complexity as a direct driver of natural rent curses, our study considers the diversity of production and quality of production system as a channel to enhance the impacts of digitalization on natural rents. With this purpose, we analyze the data for 26 European Union countries over the period 2011–2019. We mainly use the panel corrected standard errors (PCSE) model due to the presence of cross-sectional dependence. To check the accuracy of the conclusions, we also use a feasible generalized least squares (FGLS) estimation model to deal with variable variance as well as fixed effects. To minimize possible endogenous problems, all explanatory variables in the model are delayed by 1 year. We mainly use the panel corrected standard errors (PCSE) model due to the presence of cross-sectional dependence. To check the accuracy of the conclusions, we also use a feasible generalized least squares (FGLS) estimation model to deal with variable variance as well as fixed effects. To minimize possible endogenous problems, all explanatory variables in the model are delayed by 1 year.

The rest of the paper is organized as follows. Section 2 provides a review of relevant literature. Section 3 presents the model, data,

1 According to the World Resources Forum (2021), Europe's share in worldwide resource extraction is 1.5 times higher than the share of the African continent and Europe is increasingly importing natural resources from other world regions.

and estimation method, while Section 4 reports empirical results and discussion. Section 5 concludes the paper.

2. RELATED WORKS AND HYPOTHESIS DEVELOPMENT

2.1. Digitalization and Natural Resources Rents

The literature has indicated different impacts of digitalization on the economy. Not only are economic and social interactions affected by digitalization, but so are manufacturing and management processes. Hence, the influence of digitalization on natural resources consumption is convoluted, regarding not only favorable but also unbeneficial effects. Natural resources and energy are indispensable inputs for production operations by industries. The higher level of energy and resource consumption causes greater carbon emissions, thus leading to more serious environmental issues. In this paper, we investigate the relationship between digitalization and natural resources rents by studying the effects of digitalization on some fields such as energy efficiency, green consumption, and manufacturing, as well as the technology's rebound effects on energy consumption and the environment.

2.1.1. Influences of digitalization on energy efficiency

The invention and widespread application of the Internet have significantly accelerated the growth of information. With an improvement of the processing speed and a large amount of information, people can receive a substantial amount and a wide variety of knowledge faster and more comprehensively as long as they have more searching effectiveness and low-cost internet accessibility. Aside from data collecting, the rapid growth of cloud computing and big data, as well as multiple communication channels, has enabled more effective but lower costs information transfer and synchronization among individuals and specialists as well as independent of time and space constraints (Spiezia, 2011). Workers can then take this information advantage to improve their expertise, conduct more R&D activities, and continuously achieve new professional skills. As a result, human capital is strengthened, which contributes positively to advanced technical innovation efforts (Ferro, 2011; Haini, 2019). This effect is not restricted to any country. Instead, the global networks and Internet platforms encourage cross-border knowledge and technical spillovers through faster information distribution and interchange, as well as employment mobility. When the advanced technology system develops, it unremittingly enhances the human capital value and accelerates the introduction and spread of technology across multiple sectors globally (Basu and Fernald, 2007; Ceccobelli et al., 2012). Furthermore, robust financial development in a digital era also contributes to the above technological improvement process and upgrading of industrial structure. The application of the Internet in the finance sector not only enables the appearance of new finance models and credit channels but also permits transactions between investment funds and enterprises across cross-border and time boundaries (Salahuddin and Gow, 2016). Moreover, the development of funding and credit sources will also provide finance for R&D operations, particularly investments in green innovation as well as compliance with environmental requirements (Faisal et al., 2018; Owusu-Agyei et al., 2020; Tamazian et al., 2009; Salahuddin et al., 2015).

As the advanced level of production equipment is enhanced, each stage in the production process will be more accomplished, leading to the efficiency of the whole process. Additionally, emerging high-energy advanced technologies will also substitute low-energy technologies (Airehrour et al., 2016) as well as technology-intensive products (with high technical content) for traditional products that use many resources (Li et al., 2019). If the green production process and management of new green product development are optimized resulting in productivity and market diversification, the benefits of internet technology can enhance widely not only within the information technology production department but also from digital to non-digital companies (Dunnewijk and Hultén, 2007). On the other hand, the differences between qualifications and production capacity among industries with different technology and energy-intensive levels will lead to an unequal distribution of resources, in which priority is given to more efficient technology-intensive industries.

Following the time, the industrial structure will shift significantly in the direction of concentration that increases the share of technology-intensive industries while reducing that of energy-intensive and environmentally harmful industries (Qin et al., 2017). Relying on the outstanding advantages, digitization will accelerate this process through two key transmission channels, including enhanced competitiveness and the sharing of innovative knowledge with lower cost among worldwide enterprises (Vassileva et al., 2012). On this basis, it is clear that the positive change of the industrial structure improves the efficiency of ES while simultaneously minimizing the amount of energy consumption. These favorable effects have been demonstrated in many previous studies, such as Collard et al. (2005) for the French service sectors, Bernstein and Madlener (2010) and Ishida (2015) for the European manufacturing sectors, Takase and Murota (2004) for Japan, and Rent et al. (2021) for China.

2.1.2. Influences of digitalization on natural resource production

Although digitalization cannot force individuals and businesses to reduce their energy consumption to minimize carbon emissions, it can encourage them to change their production orientation in this direction. Moyer and Hughes (2012) argue that information and communication technologies (ICTs) enhance green consumption and production by lowering renewable energy costs. The emergence of the "smart grids" system has enhanced the role of digitalization in monitoring the efficient distribution of energy supply and demand, simultaneously boosting productivity and reducing transmission errors, thereby lowering manufacturing and consumption costs. Based on this system, individuals and businesses are free to conduct transactions with the grids. Similarly, Verma et al. (2020) claim that as long as the process of production, distribution, and the integration of natural resources into the present centralized energy system is improved thanks to the achievements of digitization, the resources, and energy structure will quickly transform to the trend of applying more renewable energy. Modern equipment, AI technology, or weather forecasting also play an important contribution in this transformation because they provide more exhaustive information about consumption and production trends and technology performance as well as driving efficiency participation of businesses.

2.1.3. The "rebound effects" of digitalization

Although digitalization positively impacts many dimensions of the economy and society, there still exist many potential harmful risks to natural resource consumption, thereby the environment due to the complexity of the relationship among them. Specifically, digitization can cause "rebound effects" on economic growth, trade, financial development, energy effectiveness, and green innovation. From the negative perspective, the development of digitization and advanced technologies as well as its spillover effects on digital industries can stimulate the economy to produce more and more (Salahuddin and Gow, 2016), but this economic growth is exchanged at the expense of the environment. Many classic theories show that an increase in income levels will increase energy and resource consumption, thus the achievements of digitization such as high incomes, developed financial institutions, convenient commerce, and inexpensive financial transactions, can enhance total household consumption of goods and services (Jalas, 2009; Blum et al., 2018). Consequently, the environment will have to endure much more burdens. Furthermore, the nominal market price may fall due to the enhancement of energy efficiency, resulting in rising energy consumption (Yang and Li, 2017). Sometimes, the increasing process is even supported by the benefits of the digital financial system, leading to a multifold intensification in total consumption. The rebound effects may also be the outcome of own green innovation, which is supposed to be the solution to protect the environment. Because these innovations require not only "green" inputs but also "brown" ones in production activities (Jenkins et al., 2011; Kemp-Benedict, 2014) as well as requiring the development of specialized infrastructures (Font Vivanco et al., 2014), thereby green innovation will associate with more energy consumption and more emissions (Huberty et al., 2011, Sorrell, 2007).

In fact, the favorable relationship between digitization and resource consumption and carbon emissions has been demonstrated in previous empirical studies. For example, Salahuddin and Alam (2016) find that internet technology adoption is associated with higher electricity consumption in OECD countries in both the short and long term. The positive relationship between ICTs and electricity consumption is also confirmed to exist in emerging countries (Sadorsky, 2012). Takase and Murota (2004) demonstrate a relationship between ICTs and energy utilization in the US. At the same time, Longo and York (2015) also confirms this relationship when analyzing data for an international sample for the period 1990–2010.

Because the impacts of digitalization on energy security are described in a diversity of dimensions, both positive and negative, we believe that this relationship follows a non-linear mechanism.

H_{1a}: There is a positive relationship between digitalization and natural resources rents.

H_{1b}: There is a negative relationship between digitalization and natural resources rents.

2.2. The Role of Economic Complexity

Hidalgo et al. (2007) propose the core-peripheral structure theory to describe the specific characteristics of the manufacturing process. He argues that the manufacturing process of different products can be divided into two crucial parts. The product core implies the production of metal products, machinery, and chemicals (allowing for closer product probabilities). In contrast, the periphery implies products such as fishing, tropics, garments and textiles, mining, and agriculture. Economic complexity (EC), similar to energy security, is a multidimensional concept. According to Stern (2004), to identify the complexity, it is necessary to consider the economy in interaction with four key sectors consisting of scale, product restructuring, technological progress, and transformation of the input structure. When entering the development process, the economy mainly manufactures products of low complexity, so EC is characterized by peripheral production. Lapatinas et al. (2019) claim that the specialized characteristics of these industries lead to difficulties in innovation, simultaneously the lower environmental effects. Gradually, products in the periphery will be replaced by-products in the core during the transition to a complex economy (Hausmann, 2014; Hidalgo and Hausmann, 2009; Hidalgo et al., 2007). This process is also associated with the substitution of heavy industries (the product mix is more diverse and harmful to the environment) for traditional nature-dependent industries, ultimately resulting in broader spillovers of new production activities (scale effect) (Stern, 2004). However, in this stage, environmentally friendly technologies are still considerably limited due to high set-up costs, leading to an increase in energy consumption (Liddle and Lung, 2010; Madlener and Sunak, 2011). Therefore, the economic complexity restructuring in the early stage increases the quantity and intensity of natural resource energies.

As the rise in diversity of product and quality and production system reaches to a certain extent of production scale (Stern, 2004), new technological advances can resolve issues of energy consumption, contributing to increased energy consumption efficiency and energy saving (Can and Gozgor, 2017), which lead to a reduction in the intensity and quantity of natural resource utilization. Hidalgo et al. (2007) also assert that the increase in economic complexity will enhance national income and economic efficiency. Due to income and awareness enhancement, people will pay more attention to environmental issues (Galeotti et al., 2009; Lee and Lee, 2009; Martínez-Zarzoso and Maruotti, 2011). Firms are also aware of the urgency in the transformation to environmentally friendly production to develop and compete in the new context, as well as please the demand of consumers and social acceptance (European Commission, 1999; International Trade Centre, 2001; Kennett and Steenblik, 2005; Sinclair-Desgagné, 2008). As a result, the production process has a variation in input structure from "green" inputs to "brown" inputs. In short, as the economic complexity enhances, it minimizes the consequences of environmental pollution by enhancing the decreasing effects of digitalization on natural resource consumption.

When the economic complexity is maximized, that is product and production diversities and capacities are fully utilized, countries must conduct strategic innovations and develop new industries and adopt the transformation process. According to Stern (2004), during this period, the product structure shifting from the core to the periphery will be replaced by the structure shifting from resource-intensive heavy industry to enhance manufacturing and service sectors (Dinda, 2004). The outcome of this process leads to the expectations of sustainable development by institutions. Therefore, the share of natural resource high-intensive industries will be gradually substituted by high-intensive ones. Furthermore, previous studies in the literature reveal the positive effects of digitalization on economic growth. However, these effects are conditional on the technology level. Hausmann et al. (2007) develop an index that measures the quality of countries' exporting goods to reveal that countries perform better if there is a more sophisticated set of goods. As a measure of product and production sophistication, the issue of economic complexity in explaining the difference in effects of digitalization on natural resources rents is increasingly attracting more attention.

Based on our discussion, we hypothesize:

H_2: The positive effect of digitalization in reducing natural resources rents becomes more sizable for countries with a higher economic complexity performance.

3. EMPIRICAL METHODOLOGY

The model used to investigate the nexus of digitalization and environmental performance (EP) can be presented as follows:

$$NR_{it}=\beta_0+\beta_1\ DT_{i,t}+\beta_2\ EG_{i,t}+\beta_3\ GEx_{i,t}+\beta_5\ POPU_{i,t}+\beta_5\ FDI_{i,t}+\beta_6\ CAP_{i,t}+\varepsilon_{ijt}, \quad (1)$$

where i and t respectively represent country i and year t, and ε_{ijt}, is the error term.

3.1. Natural Rents

Although Canh et al. (2020) argues that there are many kinds of resources, for example, gems, opium, oil, diamonds, timbers, tin, gold, cocoa, and so on, the lack of data from the official institutions, such as World Bank for these resources rents for the international sample make us select four kinds of natural resources rents: coal rents (*Rent_Coal*), mineral rents (*Rent_Mineral*), natural gas rents (*Rent_Gas*), and forest rents (*Rent_Forest*). The total natural resources (*NR*) rents are defined in this paper as the sum of rents of these four natural resource types.

3.2. e-Government and e-Business

- Digital business: includes selling online, e-Commerce sales, e-Commerce turnover, e-Commerce web sales, and e-Business, including customer relationship management (CRM) usage and cloud usage. We take the digital business data from the European Statistics (Eurostat)
- Digital public services: Our key explanatory variable, $eGOV_{i,t}$, consists of four indicators that reflect different aspects of digitalization in public sectors, including eGOV_UC, eGOV_CM, eGOV_BM, and eGOV_KE. More specifically, eGOV_UC is a user-centricity that captures the extent to which (information about) public service is provided online, how the online journey is supported, and if public websites are mobile-friendly. eGOV_UC is calculated as a weighted average of indicators reflecting the level of online availability, usability, and mobile-friendliness. eGOV_CM is citizen mobility that captures the extent to which public services that are aimed at foreign citizens are available online, usable, and implements electronic identification (eID) and electronic documents (eDocuments) capabilities. eGOV_CM is calculated as a weighted average of indicators reflecting the level of citizen mobility online availability, usability, eID cross borders, and eDocuments cross borders. eGOV_BM is business mobility that captures the extent to which public services that are aimed at foreign businesses are available online, usable and implement eID and eDocument capabilities. This indicator is calculated as a weighted average of business mobility online availability, usability, eID cross borders, and eDocuments cross borders. Lastly, eGOV_KE is the key enabler that captures the extent to which technical pre-conditions for eGovernment service provision are used. The key enablers used for measuring the quality of the services to businesses and citizens include eID; eDocuments; authentic sources; and digital posts. We take the data for e-Government from the eGovernment Benchmarking report and studies for digitalization conducted by Capgemini. The dataset is available from 2012 to 2019.

3.2.1. Control variables

Based on the natural resource's rents literature, we select explanatory variables. Following Canh et al. (2020) and Canh and Thong (2020), we consider the effect of income level (EG)[2] as measured by real gross domestic product per capita (USD constant in 2010 $), government expenditures (GEx) as computed by taking a natural logarithm of general government final expenditures per capita, total population (POP), net foreign direct investment inflows. The incorporation of GEx into the model is to reflect the importance of the government in fixing market failures (Armey and McNabb, 2018). (FDI) is the share of GDP, and the gross capital formation per capita (CAP)[3]. Regarding the role of the FDI, Canh et al. (2021), Ndikumana and Sarr (2019), and Zafar et al., 2019) emphasize its significant effects on natural resource rents. These variables are available from the World Development Indicator (WDI). After cleaning the data, finally, our database covers 26 countries (as shown in Table A.1) between 2011 and 2019. The statistical description of all variables is outlined in Table 1. Table 2 shows a positive association between digitalization and natural resource rents through the correlation matrix across all variables.

The next step in our data processing phase examines cross-sectional dependence (CD) by applying the tests suggested by Pesaran (2021). We then use the Levin-Lin-Chu unit root test introduced by Levin et al. (2002) and the Im-Pesaran-Shin unit root test proposed by Im et al. (2003) to check the stationarity of the data with the presence of CD. We present the results in Table 3. The tests have proven the existence of CD as well as the stationarity of the first difference variables. From the econometrics perspective, we, therefore, choose the Panel Corrected Standard Error (PCSE) model as recommended by Beck and Katz (1995) and Canh et al. (2020). All explanatory

2 The relationship between economic growth and natural resources are indicated by Abdulahi et al. (2019).

3 As shown in the study of Solow (1962) and Wolff (1991), the capital investment can positively contribute to productivity, and then have effects on natural resources rents.

variables are lagged by one period as presented in Equation (1) to deal with the endogeneity stemming from the simultaneous relationship between digitalization and natural resources rents. We also use the Feasible Generalized Least Squares (FGLS) as an alternative model, which is expected to solve the potential problem of heteroscedasticity in Equation (1) as argued by Canh et al. (2020), Le and Nguyen (2019), and Liao and Cao (2013). Thereby, we can ensure the robustness and reliability of the study's findings.

Another concentration of this paper is to investigate the moderating role of economic complexity on the nexus between digitalization and natural resources rents. To achieve this purpose, we incorporate interaction between economic complexity and digitalization variables. To capture the level of economic complexity, this paper employs the economic complexity outlook index (COI), which measures how easy it is for a country to diversify its economy. A high COI indicates a large number of nearby complicated items that rely on similar skills or know-how that are now being produced. Complexity outlook captures the connectedness of a country's existing capabilities to promote easy (or hard) diversification into related complex production. A low complexity outlook means that countries face difficulties to

Table 1: Description of variables

Variable	Definition	Measure	Source	Obs	Mean	SD	Minimum	Maximum
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 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, 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
eGOV_UC	User centricity	The user-centricity index is a weighted average of online availability, usability, and mobile-friendliness	eGBR	208	78.39	12.96	44.00	97.25
eGOV_BM	Business mobility	The business mobility index is a weighted average of online availability, usability, eID cross borders, and eDocuments cross the border	eGBR	208	65.11	17.84	9.00	100.00
eGOV_KE	Key enablers	The key enablers index as a weighted average of eID, eDocument, digital post, eSafe and single sign on	eGBR	208	54.06	25.88	0.00	99.00
EG	Real output growth	The real GDP per capital (constant 2010 US dollars)	WDI	234	36.12	25.07	1.02	111.15
GEx	GEx	The log of general government final consumption expenditure per capita	WDI	234	24.55	1.49	22.12	27.29
POPU		The total population		234	15.86	1.24	13.16	18.02
FDI	Net inflow of FDI	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	39,587.80

The information used to calculate the overall digitalization is sourced from various surveys, including Eurostat - Community survey on ICT usage in Households and by Individual, Eurostat - ICT Enterprises survey, eGovernment Benchmarking Report. WDI: World Development Indicator, FSSDA: Finnish Social Science Data Archive, WBGI: World Bank Group Indicator, SD: Standard deviation, NR: Natural resources, FDI: Foreign direct investment, CRM: Customer relation management, GDP: Gross domestic product, eID: Electronic identification, ICT: Information and communication technology, GEx: Government expenditure obtain new know-how because few products are a short distance away[4]. The COI is sourced from the MIT Media Lab's Observatory of Economic Complexity. For further analysis, the association between digitalization and four types of resource rents as well as the moderating role of economic complexity on this link are also investigated.

4. EMPIRICAL RESULTS

4.1. Baseline Results

By employing the PCSE estimate, Table 4 presents the effect of digitalization on natural rents. We find that except for "the cloud usage" and: user centricity," which have no statistically significant effect on natural resources rents, the remaining factors of digital business and digital public services have a positive effect on total natural rents. In other words, the digital transformation process in the business and public sectors increases natural resource rents. A similar finding on this link can be also found in the literature. For example, Sadorsky (2012), Salahuddin and Alam (2016), and Longo and York (2015) reveals that digitalization leads to more consumption of energy, while the pollution emission results from energy use (Can and Gozgor, 2017; Bekun et al., 2019; Oberschelp et al., 2019). Further, the development of digital business and various information and communication technologies would further intensify those impacts by fostering technological and trade-related R&D spillover effects (Basu and Fernald, 2007; Ceccobelli et al., 2012; Dunnewijk and Hultén, 2007) and hence, accelerating the diffusion of green technologies across sectors and countries. Regarding the control variables, the results present that the increase in population and gross capital formation per capita has a positive impact on natural rents. In contrast, increases in real output growth and government spending help reduce natural rents. It implies that those are vital parameters for countries aiming at reducing natural rent-seeking. For a robustness check on our findings, the FGLS model is applied, and the results are outlined in Table A2 in Appendix. The results appear quite similar as compared to those in Table 4, suggesting that we have evidence to believe in our findings.

To shed the light on the relationship between digitalization and natural resources rents, we reexamine this linkage by using diverse natural resources, including coal, minerals, natural gas, and forest. As revealed by Conigliani et al. (2018) and Zheng et al. (2018), these types of natural resources respond differently to external changes like digitalization, therefore we consider the influences of digitalization on rents of these four natural resources. Firstly, the impact of digitization on coal rents presented in Table A3 shows the positive impact of digital business on coal rents. In particular, an increase in the size of "online sales," "e-commerce revenue" and "CRP" could be positively related to higher coal rents. In contrast, scaling e-government through increased user-centricity and business mobility reduces coal rents. In other words, businesses turn to depend more on coal rents during digital transformation, while scaling up e-government reduces dependence on this type of resource. Table A4 presents the effect of digitalization on mineral rents using the PSCE estimate. The opposite

Table 2: Correlation coefficients

	NR	eCOM_ Online	eCOM_ Turn	eCOM_ Web	eBUSS_ CRP	eBUSS_ Cloud	eGOV_ UC	eGOV_ BM	eGOV_ KE	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								
eGOV_UC	0.145	0.268**	0.393***	0.438***	0.422***	0.543***	1							
eGOV_BM	0.228**	0.205*	0.346***	0.374***	0.343***	0.446***	0.614***	1						
eGOV_KE	0.212*	0.192*	0.243**	0.257**	0.255**	0.337***	0.763***	0.499***	1					
EG	0.359***	0.457***	0.436***	0.535***	0.506***	0.540***	0.369***	0.424***	0.208*	1				
GEx	0.0405	0.395***	0.313***	0.296***	0.337***	0.336***	0.306***	0.0848	0.0494	0.376***	1			
POPU	−0.104	0.128	0.0453	−0.0251	0.0293	0.000865	0.0887	−0.143	−0.127	−0.0797	0.771***	1		
FDI	0.0589	0.0178	−0.0569	−0.0440	−0.0272	−0.0264	0.0472	−0.143	0.248**	0.0514	−0.0764	−0.133	1	
CAP	0.432***	0.486***	0.589***	0.678***	0.647***	0.591***	0.407***	0.411***	0.226**	0.710***	0.326***	−0.093	0.0148	1

P<0.05, **P<0.01, ***P<0.001. NR: Natural resources, FDI: Foreign direct investment, GEx: Government expenditure

4 For further description of ECI and COI, please access https://atlas.cid.harvard.edu/glossary.

Table 3: Cross sectional dependence tests and stationary tests

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
eGOV_UC	34.59***	−2.13**	−3.15***	DeGOV_UC	−10.94***	−5.08***
eGOV_BM	18.21***	−5.45***	−2.00**	DeGOV_BM	−17.51***	−3.71***
eGOV_KE	17.95***	−4.90***	−3.47***	DeGOV_KE	−21.33***	−4.85***
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***

Regarding the CD test, the null hypothesis is that the cross-section is independent. P-value is closed to zero, implying that data are correlated across panel groups. Regarding the Im-Pesaran-Shin test, the null hypothesis is "All panels contain unit root" and the alternative hypothesis is "Al least one panel is stationary. N/A: Not available, CD: Cross-sectional dependence, NR: Natural resources, FDI: Foreign direct investment, GEx: Government expenditure. ***P<0.01, **P<0.05, *P<0.1

Table 4: Digitalization and natural rents: The panel corrected standard error estimates

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web sales	e-Business: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.03***	0.03**	0.07***	0.03**	0.01	0.00	0.01***	0.01***
	(0.009)	(0.015)	(0.021)	(0.015)	(0.005)	(0.006)	(0.002)	(0.003)
L.EG	−0.02**	−0.02	−0.01	−0.02	−0.01	−0.02**	−0.02***	−0.01
	(0.009)	(0.011)	(0.011)	(0.011)	(0.014)	(0.010)	(0.008)	(0.008)
L.GE	−1.22***	−1.16***	−1.34***	−1.16***	−1.00***	−0.81***	−0.90***	−1.12***
	(0.222)	(0.252)	(0.261)	(0.252)	(0.189)	(0.128)	(0.188)	(0.210)
L.POPU	1.28***	1.25***	1.45***	1.25***	1.05***	0.87***	0.99***	1.23***
	(0.254)	(0.289)	(0.301)	(0.289)	(0.208)	(0.161)	(0.223)	(0.250)
L.FDI	0.07 (0.185)	0.14	0.22	0.14	−0.04	0.05	0.13	−0.05
		(0.177)	(0.167)	(0.177)	(0.209)	(0.167)	(0.158)	(0.167)
L.CAP	0.28***	0.26***	0.22***	0.26***	0.22***	0.27***	0.27***	0.25***
	(0.063)	(0.067)	(0.065)	(0.067)	(0.062)	(0.062)	(0.058)	(0.054)
Observations	208	208	208	208	112	182	182	182
R^2	0.352	0.335	0.365	0.335	0.332	0.313	0.326	0.347
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

findings to the effects of digitalization on coal rents are revealed here. We find that digital public services positively affect mineral rents as reflected by the positive impact on user-centricity. In contrast, out of the five factors that make up a digital business, three have the effect of reducing mineral rents (e-Commerce turnover, e-Commerce web sales, and CRP), while the other two (Online selling and Cloud) have a positive effect on mineral rents. Tables A5 and A6 show the effect of digitalization on gas rents and forest rents, respectively. The results show that increasing the size of digital public services induces a higher dependence on both gas and forest rents. The change in gas rents and forest rents is different from the process of digitalization. In particular, the level of dependence on gas resources also increases when businesses adopt digital transformation. whereas the three factors (e-commerce turnover, e-commerce web sales, and CRP) of digital business that have a negative impact on mineral rents also have a similar impact on forest rents.

4.2. Moderating role of Economic Complexity

One of the most important contributions of this paper is to indicate the importance of economic complexity in moderating the relationship between digitalization and natural resources rents. The result of this analysis is summarized in Table 5. The coefficient between digitalization and economic complexity proxied by the COI is statistically significant and negative, suggesting that the economic complexity negatively moderates this link. In other words, countries featured by a high level of economic complexity (i.e., an improvement in knowledge materialized in a nation's product systems) is a critical driver to make digitalization, both in the business and public sector, effective in shrinking the natural resources rents at the country level. The results are critically important when they show that the digital transformation towards the goal of reducing dependence on natural resources cannot be fooled but needs to be implemented in countries characterized by

Table 5: Moderating roles of economic complexity

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Business: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.11***	0.04 (0.024)	0.10***	0.04 (0.024)	0.03**	−0.01	0.01	0.02***
	(0.025)		(0.037)		(0.017)	(0.017)	(0.009)	(0.005)
L.ECI	1.05***	1.35***	1.48***	1.35***	1.28***	0.08	0.52	0.91***
	(0.164)	(0.285)	(0.316)	(0.285)	(0.335)	(0.737)	(0.364)	(0.191)
L.ECI*DT	−0.08***	−0.07***	−0.10***	−0.07***	−0.05***	0.00	−0.01	−0.01***
	(0.017)	(0.018)	(0.025)	(0.018)	(0.016)	(0.010)	(0.006)	(0.003)
L.EG	0.04***	0.03**	0.02**	0.03**	0.02	0.03**	0.03**	0.03***
	(0.011)	(0.012)	(0.011)	(0.012)	(0.014)	(0.013)	(0.011)	(0.009)
L.GE	−1.48***	−0.97***	−0.96***	−0.97***	−0.40	−1.28***	−1.35***	−1.48***
	(0.264)	(0.315)	(0.287)	(0.315)	(0.320)	(0.160)	(0.224)	(0.179)
L.POPU	1.30***	0.84**	0.87***	0.84**	0.19	1.17***	1.26***	1.42***
	(0.283)	(0.347)	(0.317)	(0.347)	(0.355)	(0.185)	(0.240)	(0.208)
L.FDI	0.14	0.09	0.20	0.09 (0.140)	−0.09	0.00	0.03	−0.12
	(0.143)	(0.140)	(0.156)		(0.140)	(0.103)	(0.108)	(0.112)
L.CAP	0.11	0.16**	0.12	0.16**	0.11	0.19**	0.18***	0.18***
	(0.070)	(0.079)	(0.076)	(0.079)	(0.076)	(0.075)	(0.064)	(0.052)
Observations	200	200	200	200	109	175	175	175
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

better quality and diversification of the productive system. In addition to the direct effects of the economic complexity on the natural resources rents as indicated by Canh et al. (2020), the importance of economic complexity is also shown by a definite condition for ensuring the success of a different factor or strategy in reducing the dependence on the natural resources. This could be explained by the positive influence of internet technology on human capital and financial development that, in turn, support R&D activities and technological progress (Ferro, 2011; Haini, 2019; Salahuddin and Gow, 2016; Spiezia, 2011). The technological advancement, in turn, creates the upgrading of industrial structure from traditional resource-intensive to technology-intensive and allow the replacement of low-energy equipment to high-energy ones as well as the development of more eco-friendly technologies (Airehrour et al., 2016; Li et al., 2019; Rent et al., 2021). Similar to the previous analysis, we also apply the different econometric techniques to confirm the consistent results across the various estimations as reported in Table A7 in Appendix. Hence, this observation is a notable contribution to the literature since it implies that the economic complexity or the quality and diversification of the production system is the key variable for the digital economy aiming at shirking the natural rent-seeking. Subsequently, we turn to analyze the moderating roles of economic complexity on the link between digitalization and rents of four natural resource types, including coal rents, mineral rents, natural gas rents, and forest rents, and we report the results in Tables A7-A11 in Appendix. Despite the fact that the digitalization of the business and public sector has a different influence on rents of these four natural resources, the economic complexity still plays a vital role in ensuring the efficiency of digitalization in pursuing a reduction of countries' dependency on natural resources.

5. CONCLUSIONS

We are the first to empirically analyze the nexus of digital transformation and natural rents. By using the international sample of 26 European countries, we reveal interesting findings. Firstly, the study examined the effect of digitalization on natural rents and the components of natural rents. We want to emphasize that digital businesses and digital public services positively affect total natural rents. Moreover, the digital businesses are increasing influences on coal rents, and gas rents, while the larger size of digital public services induces a higher dependence towards mineral rents, gas rents, and forest rents. In contrast, digital public services tend to reduce coal rents, and digital businesses decrease mineral rents and forest rents. More importantly, there is a reduction in total natural rents for countries with a high level of economic complexity.

On the policy front, as far as we have analyzed in the long term, the scale-up of digitalization has the effect of reducing natural resource consumption. Therefore, continuous investment in digitalization across sectors is necessary to ensure the security of natural resources. The increasing trend of digital transformation during the COVID-19 crisis and its permanent changes to operation and management practices among firms and governments implies a good sign to overall natural resource security. Furthermore, accelerating the diffusion of technology for better energy efficiency and combining more stringent environmental regulations and standards in the development agenda are crucial strategies for these countries to reduce stress on energy and natural resource security. Maximizing economic complexity, therefore, represents an important chance to improve energy security.

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APPENDIX

Table A1: Countries in the sample

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

Table A2: Digitalization and natural rents: The Feasible Generalized Least Square estimates

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.03***	0.03**	0.07***	0.03**	0.01 (0.011)	0.00	0.00	0.01*
	(0.011)	(0.017)	(0.020)	(0.017)		(0.009)	(0.006)	(0.005)
L.EG	−0.02*	−0.02	−0.01	−0.02	−0.01	−0.02**	−0.02*	−0.02**
	(0.011)	(0.013)	(0.012)	(0.013)	(0.015)	(0.011)	(0.012)	(0.011)
L.GE	−1.22***	−1.16***	−1.34***	−1.16***	−1.00**	−0.81***	−0.88***	−0.90***
	(0.287)	(0.303)	(0.290)	(0.303)	(0.409)	(0.306)	(0.305)	(0.276)
L.POPU	1.28***	1.25***	1.45***	1.25***	1.05**	0.87**	0.97***	0.99***
	(0.323)	(0.342)	(0.330)	(0.342)	(0.462)	(0.344)	(0.356)	(0.319)
L.FDI	0.07 (0.223)	0.14	0.22	0.14	−0.04	0.05	0.05	0.13
		(0.229)	(0.224)	(0.229)	(0.280)	(0.218)	(0.218)	(0.220)
L.CAP	0.28***	0.26***	0.22***	0.26***	0.22***	0.27***	0.26***	0.27***
	(0.039)	(0.045)	(0.044)	(0.045)	(0.049)	(0.039)	(0.039)	(0.038)
Observations	208	208	208	208	112	182	182	182
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A3: Digitalization and coal rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.00***	0.00***	0.00 (0.001)	0.00***	−0.00	−0.00*	−0.00***	−0.00
	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L.EG	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L.GE	−0.13***	−0.13***	−0.12***	−0.13***	−0.09***	−0.09***	−0.09***	−0.09***
	(0.020)	(0.022)	(0.021)	(0.022)	(0.006)	(0.005)	(0.005)	(0.005)
L.POPU	0.15***	0.15***	0.15***	0.15***	0.12***	0.11***	0.11***	0.11***
	(0.024)	(0.026)	(0.025)	(0.026)	(0.008)	(0.006)	(0.006)	(0.006)
L.FDI	0.00	0.01 (0.006)	0.01	0.01	0.01	0.01*	0.00	0.01**
	(0.006)		(0.006)	(0.006)	(0.005)	(0.003)	(0.002)	(0.004)
L.CAP	0.00***	0.00 (0.001)	0.00**	0.00	0.00**	0.00***	0.00***	0.00***
	(0.001)		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	208	208	208	208	112	182	182	182
R^2	0.372	0.372	0.365	0.372	0.413	0.402	0.422	0.400
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A4: Digitalization and mineral rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User Centricity	Business Mobility	Key Enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.00*	−0.00***	−0.00**	−0.00***	0.00***	0.00*	0.00	0.00
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
L.EG	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
L.GE	−0.17***	−0.16***	−0.16***	−0.16***	−0.16***	−0.15***	−0.14***	−0.14***
	(0.035)	(0.034)	(0.034)	(0.034)	(0.026)	(0.028)	(0.026)	(0.024)
L.POPU	0.20***	0.19***	0.19***	0.19***	0.19***	0.17***	0.17***	0.17***
	(0.039)	(0.038)	(0.038)	(0.038)	(0.030)	(0.030)	(0.029)	(0.026)
L.FDI	0.01	0.00	0.00	0.00	0.02***	0.01	0.01	0.01
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.008)	(0.006)
L.CAP	0.00***	0.01***	0.01***	0.01***	−0.00	0.00***	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	208	208	208	208	112	182	182	182
R^2	0.301	0.302	0.301	0.302	0.403	0.306	0.302	0.303
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A5: Digitalization and gas rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.01***	0.02***	0.03***	0.02***	0.00	−0.00	0.00***	0.00*
	(0.003)	(0.004)	(0.006)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)
L.EG	−0.00	0.00	0.01*	0.00	−0.00	−0.00	−0.00	−0.00
	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.002)	(0.003)
L.GE	−0.39***	−0.42***	−0.48***	−0.42***	−0.34***	−0.22***	−0.28***	−0.31***
	(0.071)	(0.069)	(0.073)	(0.069)	(0.060)	(0.041)	(0.060)	(0.061)
L.POPU	0.44***	0.49***	0.56***	0.49***	0.39***	0.28***	0.35***	0.38***
	(0.082)	(0.082)	(0.086)	(0.082)	(0.066)	(0.052)	(0.073)	(0.074)
L.FDI	0.08	0.12*	0.15**	0.12*	0.03	0.07	0.09	0.05
	(0.076)	(0.072)	(0.071)	(0.072)	(0.068)	(0.071)	(0.071)	(0.068)
L.CAP	0.08***	0.07***	0.05***	0.07***	0.08***	0.08***	0.08***	0.08***
	(0.018)	(0.019)	(0.018)	(0.019)	(0.024)	(0.020)	(0.018)	(0.018)
Observations	204	204	204	204	108	178	178	178
R^2	0.381	0.382	0.428	0.382	0.414	0.354	0.358	0.360
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A6: Digitalization and forest rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.00***	−0.01***	−0.01***	−0.01***	0.00***	0.01***	0.00***	0.00***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.000)
L.EG	−0.01***	−0.01***	−0.01***	−0.01***	−0.01***	−0.01***	−0.01***	−0.01***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)
L.GE	−0.02	0.07***	0.06**	0.07***	−0.05	−0.09***	−0.02	−0.07***
	(0.019)	(0.025)	(0.026)	(0.025)	(0.040)	(0.026)	(0.019)	(0.023)
L.POPU	−0.07***	−0.16***	−0.16***	−0.16***	−0.05	−0.00	−0.07***	−0.00
	(0.021)	(0.028)	(0.030)	(0.028)	(0.046)	(0.028)	(0.021)	(0.026)
L.FDI	−0.00	−0.02	−0.02	−0.02	−0.01	−0.01	0.02	−0.04
	(0.016)	(0.022)	(0.024)	(0.022)	(0.014)	(0.020)	(0.017)	(0.028)
L.CAP	0.03***	0.04***	0.04***	0.04***	0.02***	0.02***	0.03***	0.02***
	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.002)
Observations	208	208	208	208	112	182	182	182
R-squared	0.488	0.501	0.505	0.501	0.427	0.544	0.525	0.562
Number of countries	26	26	26	26	26	26	26	26

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A7: Moderating roles of economic complexity on the link between digitalization and naturals resource rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital Business					Digital Public Services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.11***	0.04*	0.10***	0.04*	0.03*	−0.01	0.01	0.02***
	(0.018)	(0.022)	(0.027)	(0.022)	(0.017)	(0.012)	(0.009)	(0.005)
L.ECI	1.05***	1.35***	1.48***	1.35***	1.28***	0.08	0.52	0.91***
	(0.204)	(0.391)	(0.353)	(0.391)	(0.367)	(0.789)	(0.535)	(0.279)
L.ECI*DT	−0.08***	−0.07***	−0.10***	−0.07***	−0.05***	0.00	−0.01	−0.01***
	(0.015)	(0.021)	(0.025)	(0.021)	(0.015)	(0.010)	(0.008)	(0.004)
L.EG	0.04***	0.03*	0.02*	0.03*	0.02	0.03*	0.03*	0.03**
	(0.013)	(0.014)	(0.013)	(0.014)	(0.016)	(0.014)	(0.014)	(0.013)
L.GE	−1.48***	−0.97***	−0.96***	−0.97***	−0.40	−1.28***	−1.35***	−1.48***
	(0.274)	(0.340)	(0.329)	(0.340)	(0.433)	(0.306)	(0.283)	(0.280)
L.POPU	1.30***	0.84**	0.87**	0.84**	0.19	1.17***	1.26***	1.42***
	(0.300)	(0.370)	(0.357)	(0.370)	(0.485)	(0.334)	(0.310)	(0.311)
L.FDI	0.14	0.09	0.20	0.09	−0.09	0.00	0.03	−0.12
	(0.233)	(0.250)	(0.247)	(0.250)	(0.255)	(0.242)	(0.250)	(0.233)
L.CAP	0.11***	0.16***	0.12***	0.16***	0.11**	0.19***	0.18***	0.18***
	(0.040)	(0.045)	(0.044)	(0.045)	(0.049)	(0.040)	(0.039)	(0.038)
Observations	200	200	200	200	109	175	175	175
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A8: Moderating roles of economic complexity on the link between digitalization and coal rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital Business					Digital Public Services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.00 (0.000)	0.01***	0.01***	0.01***	−0.00	−0.00	−0.00	−0.00
		(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
L.ECI	−0.03***	0.06***	0.03***	0.06***	−0.04***	−0.03**	0.00	−0.01***
	(0.005)	(0.015)	(0.013)	(0.015)	(0.011)	(0.014)	(0.007)	(0.004)
L.ECI*DT	0.00***	−0.00***	−0.00***	−0.00***	−0.00**	0.00	−0.00*	0.00
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
L.EG	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L.GE	−0.12***	−0.08***	−0.09***	−0.08***	−0.11***	−0.09***	−0.08***	−0.09***
	(0.020)	(0.013)	(0.013)	(0.013)	(0.010)	(0.005)	(0.004)	(0.005)
L.POPU	0.15***	0.11***	0.12***	0.11***	0.14***	0.11***	0.11***	0.11***
	(0.024)	(0.017)	(0.017)	(0.017)	(0.012)	(0.006)	(0.005)	(0.006)
L.FDI	0.00 (0.009)	0.02	0.01	0.02	0.01	0.01**	0.01	0.01**
		(0.011)	(0.011)	(0.011)	(0.007)	(0.005)	(0.005)	(0.006)
L.CAP	0.00***	−0.00	−0.00	−0.00	0.00**	0.00***	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Observations	200	200	200	200	109	175	175	175
R^2	0.395	0.445	0.410	0.445	0.455	0.418	0.429	0.417
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A9: Moderating roles of economic complexity on the link between digitalization and mineral rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	−0.00	0.00	−0.00	0.00	0.00**	0.00***	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
L.ECI	0.01	0.10***	0.07***	0.10***	0.01	0.27***	0.14***	0.10***
	(0.009)	(0.023)	(0.018)	(0.023)	(0.016)	(0.048)	(0.031)	(0.016)
L.ECI*DT	0.00	−0.00***	−0.00***	−0.00***	−0.00	−0.00***	−0.00***	−0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
L.EG	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
L.GE	−0.18***	−0.13***	−0.14***	−0.13***	−0.16***	−0.13***	−0.13***	−0.13***
	(0.038)	(0.034)	(0.036)	(0.034)	(0.029)	(0.026)	(0.026)	(0.023)
L.POPU	0.21***	0.15***	0.17***	0.15***	0.19***	0.16***	0.16***	0.15***
	(0.042)	(0.037)	(0.039)	(0.037)	(0.032)	(0.030)	(0.029)	(0.026)
L.FDI	0.01	0.01	0.01	0.01	0.02**	0.02*	0.02	0.01
	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)	(0.012)	(0.007)
L.CAP	0.01***	0.00***	0.00***	0.00***	0.00	0.00**	0.00***	0.00***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Observations	200	200	200	200	109	175	175	175
R-squared	0.325	0.350	0.340	0.350	0.407	0.406	0.362	0.403
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A10: Moderating roles of economic complexity on the link between digitalization and gas rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital business					Digital public services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.03***	0.01**	0.04***	0.01**	0.01	−0.01	−0.00	0.00**
	(0.007)	(0.007)	(0.011)	(0.007)	(0.006)	(0.005)	(0.003)	(0.002)
L.ECI	0.29***	0.32***	0.39***	0.32***	0.39***	−0.13	0.13	0.25***
	(0.048)	(0.102)	(0.102)	(0.102)	(0.104)	(0.249)	(0.139)	(0.047)
L.ECI*DT	−0.02***	−0.01**	−0.03***	−0.01**	−0.02***	0.00	−0.00	−0.00***
	(0.005)	(0.006)	(0.008)	(0.006)	(0.005)	(0.003)	(0.002)	(0.001)
L.EG	0.02***	0.02***	0.02***	0.02***	0.01***	0.02***	0.02***	0.02***
	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
L.GE	−0.55***	−0.46***	−0.44***	−0.46***	−0.22***	−0.44***	−0.49***	−0.50***
	(0.090)	(0.096)	(0.088)	(0.096)	(0.075)	(0.058)	(0.075)	(0.062)
L.POPU	0.52***	0.45***	0.45***	0.45***	0.18**	0.44***	0.48***	0.49***
	(0.097)	(0.106)	(0.097)	(0.106)	(0.083)	(0.066)	(0.082)	(0.070)
L.FDI	0.13*	0.12**	0.16**	0.12**	0.02	0.07	0.06	0.06
	(0.068)	(0.060)	(0.071)	(0.060)	(0.043)	(0.049)	(0.050)	(0.047)
L.CAP	0.03	0.04*	0.02	0.04*	0.04	0.05**	0.05**	0.05***
	(0.019)	(0.023)	(0.022)	(0.023)	(0.025)	(0.023)	(0.019)	(0.017)
Observations	196	196	196	196	105	171	171	171
R^2	0.565	0.515	0.544	0.515	0.592	0.516	0.505	0.520
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment

Table A11: Moderating roles of economic complexity on the link between digitalization and gas rents

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Digital Business					Digital Public Services		
	e-Commerce: Online Selling	e-Commerce: Turnover	e-Commerce: Web Sales	e-Businees: CRP	e-Business: Cloud	User centricity	Business mobility	Key enablers
	NR	NR	NR	NR	NR	NR	NR	NR
L.DT	0.01***	−0.00***	−0.01***	−0.00***	0.01***	0.01***	0.00*	0.00***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
L.ECI	0.08***	0.18***	0.12***	0.18***	0.16***	0.19***	−0.13***	0.06***
	(0.021)	(0.051)	(0.037)	(0.051)	(0.034)	(0.054)	(0.050)	(0.020)
L.ECI*DT	−0.00**	−0.01***	−0.00**	−0.01***	−0.00***	−0.00***	0.00***	−0.00**
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)
L.EG	−0.01***	−0.02***	−0.02***	−0.02***	−0.01***	−0.01***	−0.01***	−0.01***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
L.GE	0.02	0.13***	0.10**	0.13***	0.04	−0.05*	−0.00	−0.04**
	(0.023)	(0.046)	(0.042)	(0.046)	(0.040)	(0.024)	(0.024)	(0.020)
L.POPU	−0.11***	−0.24***	−0.21***	−0.24***	−0.14***	−0.04	−0.08***	−0.03
	(0.027)	(0.051)	(0.046)	(0.051)	(0.042)	(0.027)	(0.026)	(0.024)
L.FDI	−0.01	−0.03	−0.03	−0.03	−0.03*	−0.01	0.02	−0.05
	(0.018)	(0.030)	(0.034)	(0.030)	(0.014)	(0.022)	(0.015)	(0.036)
L.CAP	0.03***	0.04***	0.04***	0.04***	0.02***	0.03***	0.03***	0.03***
	(0.005)	(0.006)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.003)
Observations	200	200	200	200	109	175	175	175
R-squared	0.496	0.520	0.519	0.520	0.450	0.548	0.540	0.565
Number of countries	25	25	25	25	25	25	25	25

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. NR: Natural resources, FDI: Foreign direct investment