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The effects of air transportation, energy, ICT and FDI on economic growth in the industry 4.0 era: Evidence from the United States

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ABSTRACT

This study analyses the causal and long-run linkage between air transport and economic growth. It was conducted to validate the tourism-led growth hypothesis for the United States (US) during the period 1981–2017 and includes Information and Communication Technologies (ICTs) alongside coal rents in the tourism-led growth hypothesis. This study presents a new direction for future studies by considering the relevance of the fourth industrial revolution (Industry 4.0), particularly in the US. To achieve the stated claim, this study considers as additional explanatory variables how ICTs moderate the impact of Foreign Direct Investment (FDI) on GDP. The empirical result confirms a connection between the Industry 4.0 era and the role of ICTs, which promotes substantial changes in the way of life and productivity. This has led to a vast technological advancement, which is in line with but at a faster pace than the technological advancement of previous revolutions. From empirical results, the study provides relevant policy recommendations related to the role of natural resources, new technologies and tourism on US GDP, while it also provides evidence of the positive effect of ICTs over FDI under the Industry 4.0 era.

1. Introduction

In recent decades, the air transport industry has burgeoned significantly due to increased global connectedness, accelerating the growth of most economies and especially the top earners in the tourism industry. Given this phenomenon, the role of air transport cannot be overemphasised and the demand for air transportation has grown in accordance with the ascending relevance of the tourism sector. A report by Trends (2014) affirms that tourism activities are among the significant factors that have driven growth in the aviation industry. Air transportation has gradually been enhanced in terms of service quality and price due to innovations in aircraft technologies and marketing schemes, as well as information and communication technology (UKessays, 2018). This improvement has also had a positive effect on the transportation preferences of tourists that are visiting from very long distances, many of whom are often discouraged by the cost and unease of transportation. The travel and tourism industry is regarded as the second largest industry in the world (Wikiversity, 2016). Considering the relationship between tourism and aviation, tourism and tourism-induced activities account for $896.9 billion of the $2.7 trillion of the aviation industry's Gross Domestic Product (GDP). Aviation holds about 3.6% of the world's GDP (ATAG, 2019). It can thus be concluded that in the 21st century, the tourism industry has been a central factor for economic growth, contributing around 10% of the world economy and 7% of global exports (UNWTO, 2016).

Based on the above highlights, this study focuses on the air transport industry to investigate the induced impact of the tourism sector on the US economy. Air transport is the safest and most convenient form of transportation. According to Davies and Downward (2007), the main trigger for growth in the tourism industry in a specific target destination deals with the macroeconomic environment of the descent and the target destinations, the cost of transportation, regulatory policies and also the supply chain and its performance. This analysis also considers the impact of tourism development on environmental pollution. Lee and Kwag (2013) tested the tourism led-growth hypothesis (TLGH) using carbon dioxide emissions resulting from tourism activities as a

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subject of interest, as well as including the effect of industrial production.

Tourism is regarded as “the invisible part of export” (Raspor et al., 2017) because there is no form of production to measure its impact on the growth of an economy. It is found to have a vital role in economic growth (Zhang and Cheng, 2019). Economic growth can not only be aided by labour and capital increase but also by export expansion. This procedure is the basis on which the export-led growth hypothesis was established and specifically, the tourism led-growth hypothesis (TLGH) was theoretically framed from the export-led growth hypothesis. Hence, when compared to the export-led growth hypothesis, the TLGH similarly explains likely transient relationships that exist between economic growth and tourism activities in the long and short-run (Brida et al., 2016; Etokakpan et al., 2019; Balsalobre-Lorente and Leitão, 2020). The theoretical framework for the TLGH was primarily postulated and proposed by Balaguer and Cantavella-Jordá (2002), whose study indicated that development in tourism could only enhance economic growth in one way (Zhang and Cheng, 2019).

This expansion of the tourism industry appears under a global context of the emergence of the new fourth industrial revolution (hereafter Industry 4.0) that necessitates a rethink of the developmental process of countries. The Industry 4.0 context goes beyond an extraordinary growth driven by technological advancement alone and also has embedded within it an enabling environment for the human population, including policymakers and the generality of people from all countries in the world, to create an inclusiveness in the growth process that is centred on the human future. The focus of this revolution is the creation of complications in terms of scope and complexity that will transform the global economy and create pathways for the human population, regardless of their social status, to positively impact their respective domains. The emergence of Industry 4.0 was signalled following the exponential growth of ground-breaking virtual technology, artificial intelligence and quantum technology, while the Internet has forced the world economy to establish a strategic plan to derive the benefits associated with this new revolution. However, there will be both winners and losers among the world's countries under globalisation and the 4.0 revolution, with world-leading economies such as the US being the most likely to reap the benefits as their plans will be built on the significant achievements that they have recorded in the past few decades. The US is undoubtedly one of the prominent beneficiaries of Industry 4.0 based on the considerable antecedent investment in infrastructure and interconnected information and telecommunication technologies (ICTs). Statista Research Department, a prominent statistical provider, reported in its forecast of ICTs investment in government markets from 2014 to 2025 that ICTs investment is currently assessed at 185.6 billion US dollars and will reach a peak of 239.8 billion US dollars by 2025. The extent of the considerable investment in ICTs by the US has indeed placed the US economy at the forefront of potential beneficiaries of Industry 4.0 among other leading economies. ICTs promote telecommunication infrastructures services and intelligent transport systems, which are priority key drivers of economic growth over the next decade. These advances generate a broadband network that accelerates information, the movements of goods and services and financial development in the Industry 4.0 era (Raheem et al., 2020). The demand for ICTs-related support services is driven by the promotion of economic development in the tourism industry, but there is also room for support goods and services. In this sense, a weak air transport sector, as with any other input in the economic system, can hinder efficient growth (Button, 2008). Travel and tourism are two concepts that are intertwined and are thus difficult to separate; a movement in one will produce the same effect in the other, especially the air transport system (Trends, 2014). Bearing this in mind, 1.5 billion international tourist visits were made globally in 2019, with the United States taking more than 5%, which is about 80 million of the overall visits. These statistics demonstrate that the US is one of the most visited tourist countries in the world and Wescott (2015) emphasises that regulations in the transportation industry have a direct effect on the tourism industry.

Moreover, Smith (2018) notes that the US is the third-largest coal-producing country behind China and India, so it is necessary to study the effect of this natural resource on the economy. The assumption that energy is fundamental to the growth of an economy together with the rapid increase in global population and economic activities has also necessitated the need for more energy generation. A significant challenge posed in the energy sector is its negative effect on green growth, climate change and global warming. A possible solution to this challenge has been proposed in the form of using coal rents (percentage of GDP) as part of total natural resources. The World Bank (2014) advises that coal rents are defined as the disparities between the measure in value of coal production (soft and hard) and their total costs of production at world prices. Coal is regarded as the most abundant and widely used energy source in the world (Irwandi, 2018), while its acceptance can also be attributed to its reliability and affordability concerning sources (Anoruo, 2017). In 2017, China was the world's largest coal-producing country, while Indonesia was fifth; in 2014, the US was the second-largest coal producer with 922mt but it has now fallen to third place, reducing its production by almost a third after a brief rise in 2016–17 (IEA, 2019). Several reports confirm that US coal production will continue to fall, with predictions varying from 24% to 20% between 2019 and 2020 (EIA, 2020; Beér , 2020). However, it should be noted that these predictions will need to be revised following the COVID-19 crisis. In years to come, countries will be required to adopt policies that aim to generate more efficient processes (Farhani and Balsalobre-Lorente, 2020). Some countries such as Indonesia and the US are reported to have made economic progress through coal production as it contributes to the country's revenue in the form of tax (Irwandi, 2018). Furthermore, under an Industry 4.0 scenario, this study explores the impact of ICTs on economic growth, presenting the effects of the interaction between ICTs and FDI. The empirical results aim to reduce a previous empirical gap and will not only shape valuable policy recommendations but also generate new lines of research. This view relates to the responsibility that ICTs have in generating the creation of new opportunities to enhance production processes or correcting market failures as a consequence of information asymmetries (Kumar et al., 2019). Sinha and Sengupta (2019) found that ICTs are the most critical driver to enhance transport, trade and financial infrastructure. Rehman et al. (2019) concluded that it is necessary to promote the ICTs sector to assist with inbound tourism and economic growth.

This study considers the effects of ICTs and Industry 4.0, which fills a gap in the TLGH empirical literature. To develop this research, Section 2 presents a literature review that incorporates relevant studies in the field of TLGH, as well as considering the pivotal effect of coal rents on economic growth and ICTs and FDI. Section 3 contains the empirical methodology and presents the main hypothesis that will be tested, while Section 3 presents the results and discussion. The final section presents conclusions and policy recommendations.

2. Literature review

Although the tourism-led growth hypothesis has previously been tested in the US (Tang and Jang, 2009), in the case of Turkey, the TLGH hypothesis was also validated via a gravity model (Ulucak et al., 2020b). Additionally, Eyuboglu and Eyuboglu, 2020 confirmed the TLGH in Argentina, Turkey and the Philippines and also established an asymmetric causality nexus between tourism development and economic growth. Similarly, Nunkoo et al. (2020) present more insights into the TLGH literature with a meta survey of the decisive role of tourism development on economic growth. Furthermore, Ulucak et al. (2020a) explored the nexus between ICT and economic growth while accounting for the role of globalisation in BRICS economies between 1990 and 2015; the study validated the globalisation-induced

environmental pollution hypothesis alongside the detrimental role of ICT on the quality of the environment as a positive statistical relationship was observed between CO2 emissions and ICT. This study presents advances related to the role of coal rents in ICTs and FDI under the TLGH scenario in the 4.0 Industrial age. The motivation of this paper is to reinforce the validation of the TLGH, including the role of coal rents, ICTs and FDI on economic growth, while it also considers the dampening effect of ICTs on FDI under the 4.0 scenario.

Several studies have investigated the TLGH using additional economic growth-related variables and most of these made use of the three-variable construct, including indices of GDP; in-bound tourism measures such as arrivals, receipts, earnings, expenditures and the like; price or exchange indicators (Brida et al., 2016a). Brida et al. (2016b) investigated the linkage between air transport and economic development in Mexico, using quarterly data between the years 1995 and 2013. The nonparametric causality test revealed that a bidirectional relationship is present between air transport and economic growth (ibid.). Wadud (2014) explored the asymmetries of economic growth and fuel prices on air transport demand for the US and the empirical results evidenced asymmetry and hysteresis in air transport demand. Balsalobre-Lorente et al. (2020) showed evidence of an asymmetric behaviour between air transport and economic growth for the Spanish economy during the period 1970–2015; this study provides evidence of the positive effects of social globalisation and urbanisation on Spanish economic growth.

Other, more specific variables have also been discussed in previous studies, including the real exchange rate, which is usually included to account for the level of openness of the country under investigation; Jackman and Lorde (2010) employed household expenditures; Durbarry (2004) included physical and human capital with export. Ghartey (2013) introduced a different perspective to capture structural changes with the effect of a natural disaster (hurricane) as it relates to tourism development. Similarly to Ghartey's research on natural disasters, the more recent study by Zhang and Cheng (2019) considered the effect of a significant earthquake on tourism development in several countries. Alexander et al. (2015) considered the impact of air transport on economic growth in Nigeria as a developing economy and found that the dynamic ordinary regression line equation and error correlation models indicated a positive influence between the pair within the period under study. The cointegration test in this study (ibid.) shows equilibrium in a long-run interaction between air transportation and GDP, while there is a one-way directionality between air transport and economic growth. Ishutkina and Hansman (2009) developed a global perspective to measure the relationship between air transport action passengers and GDP, including 139 nations in their study and drawing 22 representatives that cover various categories including likely interaction, income and geography. The study employed two reasonings, the first of which questioned the ways in which the air transport flows of passengers and freight allow the movement of goods, services, labour, tourism, knowledge, investment and remittances among the countries' economies; while the second investigated the way that air transport flows can influence the nation's demand, business situations and other factors (Ishutkina and Hansman, 2009). A further study by Nuri et al. (2015) segmented Turkey into sub-regions to study the impact of an active airport and the frequency of its traffic on the macroeconomic measure. They used the fixed effect and two-stage least square methods and applied these to panel data from 26 sub-regions, concluding that active airports and busy airways have a positive impact on regional economic growth (Nuri et al., 2015). Hakim and Merkert (2016) studied the causal interaction between air transport and economic growth, using Southern Asia as a case study. A period of 42 years was considered for panel data of eight countries and the study found that there was a three to four-year time lag on both air passengers and consignment growth, revealing a long-run one-way directional causality from GDP to air transportation (Hakim and Merkert, 2016).

The linkage between energy use and economic growth has been analysed significantly in the last few decades (Gómez et al., 2018; Koçak et al., 2020; Adedoyin et al., 2020b, 2020a; Udi et al., 2020). Gómez et al. (2018) explored the causal linkage between energy consumption and income in Mexico between 1965 and 2014 and the study found the presence of breaks in the structure of the data, revealing the existence of a long-run interaction between production, labour and capital, as well as energy. Kronenberg (2004) stated that natural resources, especially coal as a source of energy, were among the first propellants of the industrial revolution. Most of the literature on natural resource abundance considers it as a blessing to the growth of countries who have them. Some of these studies also proposed that the abundance of such natural resources has been seen to negatively affect development, although it can be a blessing if there is proper management and good policies (Driouchi, 2014). Mehar et al. (2018) established that coal rents play a crucial role in economic growth and development. Coal rents comprise oil rent, gas rent, mineral rent, forest rent and coal (hard and soft) rent. Mehar et al. (2018) used cointegration, regression and vector error correlation techniques to check for relationships and causality in Pakistan and India, with their results showing that total resources rents have a positive impact on the GDP of both countries. Zhuang and Zhang (2016) examined the impact of resource rent, especially coal, on the economy of local counties in Shanxi, China. Their results indicated that natural resources harms government expenditure, which implies that abundant natural resources will make the government spend less. Apergis and Payne (2010) explored the connection between coal consumption and economic growth for 25 Organization of Economic Cooperation (OECD) countries, concluding that coal consumption was directly connected with long-run economic growth; while in the short-run, the connection between these two variables was negative. For the US, Yildırım et al. (2012) evidenced a long-run connection between coal consumption and industrial production. Driouchi (2014) considered that proper management and policy-making played a fundamental role in the impact of coal consumption on the economic growth of the coal-abundant US economy.

A new perspective was also projected by Jin and Kim (2018), whose study investigated coal consumption and economic development by comparing OECD and developing countries, as well as non-OECD countries. These authors (ibid.) showed that while long-run relationships between coal consumption and economic development did not exist in the 30 OECD countries, they were present for the 32 non-OECD countries that were examined. Jin and Kim (2018) also stated that coal consumption might halt the growth of the economy in the long term, as well as finding that non-OECD countries engaged in climate-conscious methods such as energy mix, so might gradually become less reliant on coal. They (ibid.) employed multivariate panel data analysis, cointegration tests and Granger causalities for their study. Cointegration and causality tests were also applied to Indonesia by Irwandi (2018), as this was the world's largest producer of coal for the years 1965 to 2016; through the Granger causality and vector error correlation methods, this study reveals the existence of a long-run interaction between coal consumption and economic development in Indonesia, but there is no causality. Irwandi's (2018) findings are more neutral concerning the blessing or curse perspective, which was also tested by Driouchi (2014). Gurgul and Lach (2011) approached their study by using quarterly data from the Polish economy to examine the relationship between coal consumption and the economy, using GDP as an indicator and including employment as a variable. Their study (ibid.) reveals a nonlinear causality between coal consumption and GDP and likewise for the other relationships and while they used the Toda-Yamamoto bootstrap methods, using quarterly data might have revealed more hidden patterns in the data. Ozturk and Ozturk (2018) used the Autoregressive Distributed Lag (ARDL) and Autoregressive Moving Average (ARIMA) model in their study to investigate coal consumption, technological innovation, economic growth and energy price in Turkey. They were found to be cointegrated; economic growth impacts coal consumption positively while technological innovations impact it negatively over a

long passage of time, but they both have a positive influence on coal consumption in the short-run. The ARIMA tests proposed that between the years 2016 and 2025, the average annual growth for coal consumption in Turkey will be 2.02% (Ozturk and Ozturk, 2018).

In the analysis of the dampening effects of ICT and FDI on economic growth, the basis behind this considers that ICTs add potentially positive externalities as information and profitability overflows to foreign firms. Furthermore, it is contended that information overflows are frequently fanciful since residential firms utilise reverse creation innovation and untalented specialists are generally unfit to gain from multinationals. For the most part, multinationals have lower minimal expenses because of certain firm-explicit favourable positions, so pundits contend that they can draw sought-after customers away from household firms, constraining local organisations to diminish their creation. Foreign businesses can hence, incomprehensibly, decrease the profitability of household firms, as some firm-level examinations recommend Balasubramanyam et al. (1996) study, which examined a sample of 46 creating nations and found that the impacts of FDI on development were more grounded for nations that were progressively open to exchange. They (ibid.) contended that progressive, open economies are more likely than closed economies to pull in a higher volume of FDI and advance its more proficient use.

While a few elements become possibly the most critical factor in what decides a nation's appeal to FDI, research is developing on the role of ICTs as a determinant of such speculation, which is summed up below. In advance, ICTs can generate a positive effect on development and business enterprise, which are especially significant determinants of FDI, particularly mechanically dangerous speculations, FDI in research and development (R&D) and innovation-concentrated vital partnerships. A decent ICTs foundation likewise improves the allure of nations to send out arranged FDI. ICTs offer the assessed help to encourage trading, which adds to a country's allure to outside financial specialists who are looking to set up a proximity to serve local or worldwide markets. ICT, particularly the broad utilisation of the Internet, can improve straightforwardness in nations that have it, as well as decreasing impairment, which is a hindrance to FDI (Vinod, 2005). Alfaro (2003) concluded that a rise in FDI inflows does not have to unequivocally imply an increase in the economic growth of the hosting country. Specifically Alfaro (2003) suggests that FDI inflow can present a negative or positive impact on growth, depending on the primary or manufacturing sector. This evidence reinforces the hypothesis of the present study that considers the negative impact of FDI on GDP in the US, which is related to the primary nature of FDI inflows. The consideration of ICTs will contribute to design measures that aim to correct this negative linkage. In consequence, a direct linkage between the mixed effect of ICTs over FDI and economic growth in the US is expected, contextualising Industry 4.0 over foreign business.

Assuming the relevance of ICT on economic growth, under Industry 4.0 (Chung and Kim, 2016), it will create new opportunities in sustainable industrial manufacturing (Stock and Seliger, 2016). Numerous studies have emphasised the influence of ICTs development on the expansion of economic activities, including tourism, productivity and economic growth (Chun and Nadiri, 2008; Timmer and Van Ark, 2005; Brida et al., 2016a; Erumban and Das, 2016; Toader et al., 2018; Park et al., 2018; Bahrini and Qaffas, 2019; Zhang, 2019; Rehman et al., 2019; Sinha and Sengupta, 2019; Raheem et al., 2020). In contrast, some seminar studies have suggested that ICTs stimulate the growth effect (Bresnahan and Trajtenberg, 1995; Aghion and Howitt, 1998; Helpman and Trajtenberg, 2004; Raheem et al., 2020). This growth effect is divided into direct and indirect effects; while the direct effects of ICTs consider advances in hardware and software, the indirect effects reflect the induced effects (spillovers) as a consequence of the application of ICTs in manufacturing processes. Bresnahan and Trajtenberg (1995) deemed the existence of indirect effects that arise from horizontal and vertical spillovers. Romer (1986, 1990) advise that these spillovers enhance growth and productivity and lower costs of production, while Inklaar et al. (2008) and Jorgenson and Vu (2011) suggest that they promote access to high-tech inputs. Meanwhile, Demeter et al. (2011) and Chou et al. (2014) postulate that the unrelenting effects of ICTs on growth is a positive result if the total factor productivity is affected in supply chains. This process implies global harmonisation at the country level for ICTs measures to achieve more efficient processes and economic growth. The existence of these indirect effects justifies the present study's analysis of the interaction between FDI and ICTs.

Previously, Roller and Waverman (2001) established a positive linkage between ICTs infrastructures and economic growth for a panel of 21 OECD countries between 1970 and 1990. Thompson and Garbacz (2011) showed that the implementation of telecommunication infrastructures would promote the efficiency of production at a worldwide level. evidenced similar results for the G-7 economies, while Jorgenson and Vu (2007) showed a direct linkage between ICT and economic growth for 110 countries, including the US. Seo et al. (2009) conclude that ICT investment has a positive effect on GDP growth for a panel of 29 countries and Venturini (2009) for US and EU-15 countries. Gruber and Koutroumpis (2010) found a significant impact of mobile telecommunications diffusion on GDP and productivity growth for a panel of 192 countries for the period 1990–2007. Vu (2011) explored the impact of ICT on growth for a sample of 102 countries for the period 1996–2005.

In the case of country-specific studies, several researchers have highlighted the relevance of ICT in enhancing economic growth, for example, Oulton (2012) for the UK; Daveri (2002) for EU economies; Jalava and Pohjola (2008) in Finland; Kuppusamy et al. (2009) for Malaysia; Kumar and Kumar (2012) for Fiji; Kumar and Kumar (2012) for Sub-Saharan Africa (SSA). Vu (2013) explored the impact of ICT on the economic growth of Singapore between 1990 and 2008 and found that ICTs contributed about 1% to Singapore's economic growth. Kumar (2013) obtained the same results for the Philippines and Vietnam, Kumar et al. (2015) for small Pacific island states and Kumar et al. (2016a, b) for China. In contrast, some studies have reported inconclusive results; for example, Dewan and Kraemer (2000) examined the connection between ICTs and economic growth for a selection of 36 countries over the period 1985–1993 and while they found a positive and significant linkage for developed countries, the results were not significant for developing countries.

Essentially, the evidence recommends that ICTs supports FDI either by decreasing pursuit time and related expenses or through increments in effectiveness and efficiency. ICTs and the dispersion of new ICT instruments (for example Internet-enabled cell phones) are seen as noteworthy “pull” factors for FDI in Gani and Sharma's (2003) report. Another investigation by Roghieh Gholami et al. (2006) found a causal connection among ICT and FDI in developed nations, implying that a more significant level of ICT speculation prompts an expansion in the progression of FDI but this outcome could not be reproduced for developing nations. However, there was fractional proof of the inverse causal relationship, specifically that the inflow of FDI brings additional increments in ICTs speculation and creation limit. Choi (2003) found a connection between the development of Web clients or Web hosts and FDI; a 10% expansion in Web clients or Web hosts corresponds with a 2% increment in FDI streams. This process works through the Web, helping to bring down costs by reducing scan costs for business-to-business (B2B), business-to-consumer (B2C) and business-to-government (B2G) and usually adding to the effective working of both local and foreign markets. Lower costs mean lower section obstructions and increased rivalry, which can prompt higher efficiency and more FDI.

Ko's (2007) investigation upheld the connection between the Web and FDI, finding that the positive system externalities related to Web utilisation energise FDI (Ko, 2007). Ko's review gave solid proof that the nearness of negative system externalities in creating nations disheartens internal FDI and such discoveries support an examination of the relationship between Web development and worldwide exchange.

Another report discovered that a recent 10-rate point increment in a nation's Web development prompts an approximately 0.2 rate point increment in send-out development (Freund and Weinhold, 2004). Sinha and Sengupta (2019) analysed the dynamic interrelationships among FDI inflows, ICTs expansion and economic growth in Asia-Pacific developing countries over the period 2001–2017; the empirical results showed that ICTs should be promoted to attack more high-tech FDI inflows to experiment with better economic growth. This view is associated with the theoretical approach that considers the potential for ICTs to improve competitiveness and facilitate new socio-economic development opportunities. Consequently, ICTs contribute to integrated networking among individuals, business and governments, attracting new investments at a global level (Bon et al., 2016).

3. Data collection and method research

The central hypothesis of the present study is the validation of TLGH through the connection between air transport (air transport passengers) and per capita GDP (current per capita GDP in US dollars). To reinforce the empirical results, this study also included the additional explanatory variables of coal rents (% GDP) as a measure of natural resources; the impact of ICTs; FDI inflows; the interaction between FDI and ICTs on economic growth in the US. To this end, secondary data on an annual frequency from 1981 to 2017 were retrieved from the World Bank (2020) development indicators database. Although this study mainly assesses the connection and effects of air transport (as a proxy of international tourism) and economic growth in the US during the stated period, the additional explanatory variables seek to avoid the problem of omitted variable bias, which reinforces previous empirical literature. The interaction between ICTs and FDI is assumed in the context of Industry 4.0; these fundamental forces are perceived, empirically tested and proven to be the determining factor of economic growth and their dynamics (Saidi et al. 2018, Balsalobre-Lorente et al. 2019, Farhani and Balsalobre-Lorente, 2020).

For this proposal, the following equation will be checked as the main model (Equation-1):

$$LGDP_{it} = \alpha_0 + \alpha_1 LAT_t + \alpha_2 LCR_t + \alpha_3 LICT_t + \alpha_4 LFDI_t + \alpha_5 LFDI *LICT_t \varepsilon_{it} \quad (1)$$

These variables are further expressed inU Table 1, while the main statistics and correlation matrix are shown in Table 2:

Table 2 presents the summary statistics that renders measures of central tendencies including averages, maximum and median, in conjunction with measures of dispersion of the investigated variables. At the bottom of Table 2, the pairwise relationship can be found, which highlights a strong positive relationship between economic growth and the US aviation sector (as measured by air transportation). Similarly, a positive trend between ICTs, FDI and GDP is observed. Interestingly, an inverse relationship is seen between coal rents and economic growth but these outcomes are not substantiated and thus require further investigation.

This study's main hypothesis are tested using Fully Modified Least Squares (FMOLS), Dynamic Ordinary Least Square (DOLS) and Canonical Cointegrating Regression (CCR) econometric methods. The econometric results will confirm the long-run effects of air transport (as a proxy of international tourism), addressing serial correlation and the endogeneity of regressors. These econometric methods are considered better estimators for small samples and also attempt to look at the asymptotic bias contained in the OLS estimate by including necessary leads as well as the lags in the series (Arize et al., 2000; Narayan and Narayan, 2005). The additional driving forces contribute to reinforce the main model and to contextualise the effects of ICTs within Industry 4.0 in the US.

4. Empirical results and discussions

This section focuses on the econometric results and presents a discussion of the results. As mentioned previously, this study employs six variables (Eq. (1)):

$$LGDP_{it} = \alpha_0 + \alpha_1 LAT_t + \alpha_2 LCR_t + \alpha_3 LICT_t + \alpha_4 LFDI_t + \alpha_5 LFDI *LICT_t \varepsilon_{it} \quad (2)$$

To correct endogeneity and omitted variables problems, the FMOLS, DOLS and CCR econometric methods are used. This study builds a new specification as it considers additional driving forces of economic growth; (1) information and communication technologies (ICTs); (2) coal rents; (3) foreign direct investment (FDI); (4) the interaction between FDI and ICTs for omitting biased results (Eq. (1)). Before running the econometric analysis, this study applied Alexander et al. (2015) guidance and used the ADF unit root test with a structural break (Clemente et al., 1998) to obtain the integration order of selected variables (Table 3).

The ADF (IO) and ADF (AO) tests presented in Table 3 confirm that, at the first difference, the series are stationary and integrated of order 1 -I(1)-. The structural break provides information regarding the structural breakpoint though an additive outliers (AO) model that indicates a swift change in the mean of a variable, while an innovative outliers (IO) model shows a gradual shift in the variables mean. For the analysis of sudden, gradual change, the AO model is more appropriate than the IO model, which is better suited for gradual change (Clemente et al., 1998). Several key dates during the period in question represent advances that imply a revolution in ICTs in the US; in 1986, the deregulation of basic rates for cable service was applied, based on the 1984 Cable Act; in 1996, cable entered the high-speed online data business when Tele-Communications, Inc. rolled out its @Home service in San Francisco, while Time Warner Cable launched Road Runner in Akron and Canton, Ohio and by the end of the year, six of the ten largest service companies had launched commercial cable modem services and more than 100,000 modems had been supplied; the year 2004 saw a significant breakthrough in US-China negotiations, which radically liberalised traffic rights arrangements between these two countries.

It is confirmed that all selected variables are I (1), Johansen (1991)

Table 1
Description of variables.

Variable	Description	Source
$LGDP_t$	Per capita Gross domestic product expressed in logarithms	WDI (2020)
LAT_t	***Air Transport, Passengers*** Carried: Air passengers carried include both domestic and international aircraft passengers of air carriers registered in the country, expressed in logarithms.	WDI (2020)
$LFDI_t$	**Foreign direct investment, net inflows (% of GDP)**: Foreign direct investment, expressed in logarithms.	WDI (2020)
LCR_t	**Coal rents (% of GDP):** Coal rents, expressed in logarithms, are the distinction between the value of both hard and soft coal production at world prices and their total costs of production. This variable can be considered as a proxy of natural resources	WDI (2020)
$LICT_t$	**ICT service exports (BoP, current US$)** per capita, expressed in logarithms: Information and communication technology service exports include computer and communications services and information services.	WDI (2020)
$LFDI*LICT_t$	**Foreign direct investment, net inflows (% of GDP)* ICT service exports (BoP, current** US$), for testing the interaction between FDI and ICT on economic growth. This variable will validate the technological effect that ICTs exert over traditional US´s FDI inflows.	Authors computation

Table 2
Descriptive statistics & correlation matrix.

	LGDP	LATP	LICT	LFDI	LCR
Mean	10.38749	20.14114	3.441756	0.194471	−1.520569
Median	10.44911	20.19660	3.767937	0.264219	−1.641216
Maximum	11.00090	20.56004	4.866821	1.225338	−0.301474
Minimum	9.545105	19.45417	1.355467	−1.505341	−2.756962
Std. Dev.	0.432264	0.301663	1.010437	0.625529	0.580067
Skewness	−0.365664	−0.698150	−0.409181	−0.616746	0.242340
Kurtosis	1.963223	2.556670	2.141775	3.199481	3.106329
Jarque-Bera	2.481690	3.308722	2.167994	2.406995	0.379590
Probability	0.289140	0.191214	0.338241	0.300143	0.827129
Sum	384.3371	745.2222	127.3450	7.195418	−56.26104
Sum Sq. Dev.	6.726673	3.276024	36.75542	14.08632	12.11321
Correlation Matrix					
	LGDP	LATP	LICT	LFDI	LCR
LGDP	1.000000	–	–	–	–
LATP	0.983001	1.000000	–	–	–
LICT	0.990705	0.978827	1.000000	–	–
LFDI	0.716802	0.763155	0.738314	1.000000	–
LCR	−0.043671	−0.140306	−0.061044	−0.077485	1.000000

test, which combines individual tests and connects tests from individual cross-sections, which will confirm the existence of a long-run relationship among selected variables (see Table 4):

Table 4 presents results for the Johansen cointegration tests, confirming the existence of a long-run relationship among variables. Before running FMOLS, DOLS, and CCR econometric methodology, as shown in Table 5, the Diks-Panchenko (2006) nonparametric Granger test was used to examine the causality direction among the outlined variables. This test was chosen over the traditional Granger causality test because it renders robust results in the presence of asymmetry and nonlinearity.

Table 5 exhibits the causality analysis that confirms a one-way causality analysis between tourism development (air transport) and economic growth (Hakim and Merkert, 2016). This finding is insightful to the administrators of the US economy as the tourism industry is seen as a suitable catalyst for sustainable economic growth. A one-way causality relationship that validates the energy led-growth hypothesis as energy (coal rent) running from economic growth, indicates that natural resources drive economic growth. This outcome has been proven by several studies, including Emir and Bekun (2019) in Romania; Balsalobre-Lorente et al. (2018) study on EU-5 countries; Wolde-Rufael (2004) for Shangai and Wolde-Rufael (2010) in India and Japan. Gholami et al. (2005) showed a unidirectional causality running from ICTs to FDI in developed countries. This result implies that ascending ICTs infrastructures will lead to an increase in FDI inflows.

Finally, Table 6 shows the FMOLS, DOLS and CCR estimation results. The empirical analysis aligns with the aim of this paper which is to advance the evaluation of the linkage between tourism, coal rents, ICTs, FDI and the economic growth of the US during 1981–2017. The

Table 4
Johansen cointegration test.

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
$r \leq 0$	0.662634	105.7350	69.81889	(0.0000)
$r \leq 1$	0.596146	67.70454	47.85613	(0.0003)
$r \leq 2$	0.428316	35.97000	29.79707	(0.0086)
$r \leq 3$	0.314705	16.39911	15.49471	(0.0365)
$r \leq 4$	0.086654	3.172413	3.841466	(0.0749)

Note: Trace test indicates four cointegrating eq(s) at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values.

impact of these explanatory driving forces on economic growth is tested through FMOLS, DOLS and CCR techniques (Table 6). This methodology is appropriate for a nonparametric approach, which returns optimal results (Phillips and Hansen, 1990). While the FMOLS method runs adjustments for serial correlation and endogeneity; due to the existence of cointegration relationships (Phillip and Hansen, 1990; Phillips, 1995), the DOLS method implies an asymptotically efficient estimator that erases feedback in the cointegrating system (Stock Watson, 1993).

Moreover, the CCR estimator provides more convincing results than the OLS estimator, generating smaller bias than OLS or FMOLS (Montalvo, 1995). The difference between FMOLS and CCR is that the FMOLS method converts only the dependent variable and in the second step, modifies the OLS estimate in the regression. The CCR estimator is based on a transformation of the variables in the cointegrating

Table 3
ADF test with structural break: additive & innovative outliers.

Variables	ADF Test Statistic (IO)	P-Values	Breaking Point	ADF Test Statistic (AO)	P-Values	Breaking Point
Level						
LGDP	−3.328607	(0.4873)	1984	−2.065967	(0.9781)	2010
LAT	−4.456500**	(0.0485)	1998	−2.677760	(0.8389)	2004
LCR	−3.291062	(0.5083)	2003	−3.644011	(0.3100)	2007
LICT	−3.778828	(0.2452)	1996	−2.061016	(0.9786)	1985
LFDI	−7.255653*	(< 0.01)	1997	−4.194738***	(0.0997)	1995
First difference						
ΔLGDP	−4.365869**	(0.0622)	1989	−5.090742*	(< 0.01)	2008
ΔLAT	−5.056862*	(< 0.01)	1986	−5.211968*	(< 0.01)	1986
ΔLCR	−7.533006*	(< 0.01)	1995	−7.710076*	(< 0.01)	1995
ΔLICT	−9.872261*	(< 0.01)	1986	−9.889860*	(< 0.01)	1986
ΔLFDI	−7.505118*	(< 0.01)	1987	−7.874966*	(< 0.01)	1987

*99% level of significance ** 95% level of significance ***90% level of significance Vogelsang (1993) asymptotic one-sided p-values.

Table 5
Diks-Panchenko´s causality tests.

Null Hypothesis:	Causality	F-Statistic	P-Value.
LATP does not Granger Cause LGDP	LGDP→LATP	1.71183	(0.1977)
LGDP does not Granger Cause LATP		4.82619*	(0.0152)
LICT does not Granger Cause LGDP	LGDP→LICT	0.39052	(0.6801)
LGDP does not Granger Cause LICT		5.04233*	(0.0129)
LFDI does not Granger Cause LGDP	LGDP→LFDI	0.47266	(0.6279)
LGDP does not Granger Cause LFDI		3.53499*	(0.0418)
LCR does not Granger Cause LGDP	LCR→LGDP	2.88957**	(0.0712)
LGDP does not Granger Cause LCR		1.23489	(0.3052)
LICT does not Granger Cause LATP	LATP→LICT	1.86573	(0.1723)
LATP does not Granger Cause LICT		3.29347**	(0.0509)
LFDI does not Granger Cause LATP	LFDI↔LATP	3.75223*	(0.0351)
LATP does not Granger Cause LFDI		6.60977*	(0.0042)
LCR does not Granger Cause LATP	LCR ≠ LATP	0.45619	(0.6380)
LATP does not Granger Cause LCR		1.25154*	(0.3006)
LFDI does not Granger Cause LICT	LICT→LFDI	0.00436	(0.9956)
LICT does not Granger Cause LFDI		4.21218*	(0.0244)
LCR does not Granger Cause LICT	LCR ≠ LICT	0.10333	(0.9021)
LICT does not Granger Cause LCR		0.74961	(0.4812)
LCR does not Granger Cause LFDI	LCR ≠ LFDI	1.40680	(0.2606)
LFDI does not Granger Cause LCR		1.41292	(0.2592)

Note: (→) unidirectional causality, (↔) bidirectional causality; (≠) non-causality.

Table 6
Equation-1 FMOLS, DOLS & CCR econometric results (1981–2017).

Dependent Variable: LGDP	FMOLS	DOLS	CCR
LATP	0.728498*	1.111112*	0.747436*
	[7.265007]	[6.890836]	6.791678]
	(0.0000)	(0.0000)	(0.0000)
LCR	0.041444*	0.038661*	0.042286*
	[3.734469]	[2.829422]	[3.643493]
	(0.0008)	(0.0142)	(0.0010)
LICT	0.229791*	0.133995*	0.224496*
	[8.229938]	[3.011466]	[7.064169]
	(0.0000)	(0.0100)	(0.0000)
LFDI	−0.108752*	−0.214486*	−0.109874*
	[−3.141078]	[−3.422570]	[−2.578489]
	(0.0038)	(0.0045)	(0.0151)
LICT*LFDI	0.020544**	0.040052**	0.020976***
	[1.957481]	[2.217313]	[1.676374]
	(0.0597)	(0.0450)	(0.1041)
Constant	−5.015104*	−12.36877*	−5.377591
	[−2.608796]	[−4.001433]	[−2.555851]
	(0.0140)	(0.0015)	(0.0159)
R-squared	0.990173	0.998860	0.990165
Adjusted R-squared	0.988535	0.997106	0.988526
S.E. of regression	0.044323	0.020841	0.044341
Log likelihood	0.001018	0.000386	0.001018
Mean dependent var.	10.41089	10.41805	10.41089
S.D. dependent var.	0.413948	0.387403	0.413948
Sum squared resid.	0.058937	0.005647	0.058983

Notes: (*) Significant at the 1%; (**) significant at the 5%; (***) Significant at the 10%. and (no) Not Significant.

regression that deletes the second-order bias of the OLS estimator (Stock and Watson, 1993; Inder, 1993).

From Table 6, the empirical results confirm that tourism (air transport as its proxy), carbon rents and ICTs have positive elasticities for economic growth, while FDI has a negative elasticity for economic growth. The interaction between FDI and ICTs enhances economic growth, which might be due to the promotion of competitiveness and economic growth in the Industry 4.0 context (Fig. 1).

The econometric results reveal that LAT_t, increases $LGDP_t$ ($\alpha_1 > 0$) validating the TLGH for the US during the period 1981–2017. This result confirms the findings of previous literature (Tang and Jang, 2009; Brida et al., 2016), but offers a new view, where the proposed model also takes into account the role of coal rents (as a proxy of natural resources), ICTs and FDI, under an Industry 4.0. context. The coal rents (LCR_t) present a direct relationship ($\alpha_2 > 0$) with economic growth (Mehar et al., 2018). The impact of coal rents on economic growth has been mostly positive in the empirical literature (Irwandi, 2018). This study's results reveal the relevance of natural resources to economic growth in the US and how the promotion of suitable energy policies is necessary to maintain proper economic growth (Balsalobre-Lorente et al., 2018; Farhani and Balsalobre-Lorente, 2020). The econometric results of the present study also confirm that ICTs impact positively ($\alpha_3 > 0$) on economic growth (Chung and Kim, 2016; Sinha and Sengupta, 2019; among others). These results confirm the relevance of ICTs on economic growth in the context of Industry 4.0, which considers that the growth effect of ICTs will be the main driving force of economic growth in the US in forthcoming decades. The empirical results also reveal a negative connection ($\alpha_4 < 0$) between $LFDI_t$ and $LGDP_t$. This result is not new in the empirical literature since Herzer et al. (2008) used the GETS methodology to identify the presence of pernicious effects of FDI on economic growth in 44 developing countries. Meanwhile, Bruno and Campos (2013) showed that 11% of studies reflected a negative connection between FDI and economic growth; this negative linkage suggests the presence of unfair competition or pernicious economic spillovers (De Mello, 1999; Herzer et al., 2008). The negative spillovers are related to educational level, institutional quality or the primary nature of FDI inflows (Borensztein et al., 1998; Xu, 2000; Alfaro, 2003; Agbloyor et al., 2016).

Consequently, the econometric results highlight the existence of an insufficient level of manufacturing and high-tech FDI inflows in the US. Otherwise, the influence of FDI inflows on host firms is dynamic, generating a positive long-term effect on local investments from FDI spillovers (Ngouhouo, 2008). Hence, the competition generated by FDI leads to advances in productivity and capital accumulation in the host country (Lee and Tcha, 2004). Finally, the interaction between ICTs and FDI ($LFDI_t^* LICT_t$), reveals a positive impact ($\alpha_5 > 0$) on economic growth. This result suggests that ICTs contribute to correcting the negative effect of FDI inflows on US economic growth. This result is in line with Roghieh Gholami et al.'s (2006) study, which found that ICTs led to an expansion in the progression of FDI. This evidence confirms the existence of positive spillovers of ICTs over FDI, appearing to be a growth effect that requires the structural conditions of host countries to infer the adoption of foreign technologies (Hoskisson et al., 2013; Peng et al., 2008). From the econometric results, it can be suggested that the US administration needs to develop measures to consolidate a higher institutional quality level that enhances both foreign and local firms and constrains the negative bearing of FDI on growth (Wang et al., 2013).

In consequence, the econometric results demonstrate that ICT directly affects FDI inflows, forming global innovation and entrepreneurship (De Mello, 1999; Hejazi and Safarian, 1999). The US administration should therefore promote ICTs infrastructures to enable the attraction of export-oriented FDI inflows (Sinha and Sengupta, 2019). The promotion of ICTs will also have direct positive effects on the tourism industry (Kumar and Kumar, 2012, 2019), which indicates a significant interconnection between technology advancement and tourism expansion, and economic growth. In other words, technological advances will improve the effectiveness of labour in tourism-related activities and manufacturing processes; while increasing the implementation of ICTs coming from foreign nations will generate economic growth and lead to the expansion of productivity and efficiency in manufacturing processes. In consequence, the US administration should promote ICTs infrastructures, providing logistical support for export and the attraction of FDI inflows, which would promote economic growth (Dimelis and Papaioannou, 2010; Sinha and Sengupta, 2019).

In consequence, the present study highlights the value of air transport (as a proxy of the tourism industry, Balsalobre-Lorente et al.,

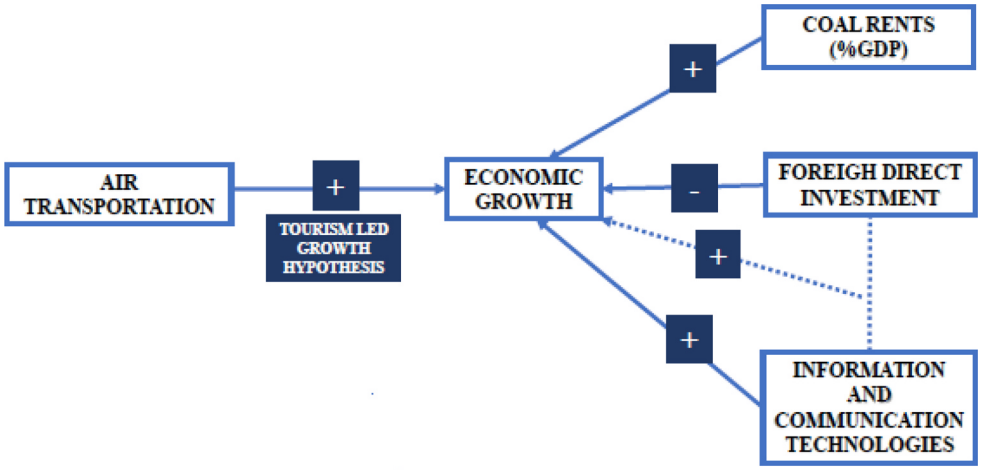

Fig. 1. Empirical Scheme.

2020) that is connected with economic growth and social development under an Industry 4.0 scenario, where the relevance of ICTs is obvious. In other words, the considerable investment made by the US economy in ICTs development has led to the US ranking as the most significant designation of foreign direct investment in the world, which has also made the economy a frontline beneficiary of the packages generated by Industry 4.0. A United Nations Conference on Trade and Development (UNCTAD) survey of multinational enterprises (MNEs) reports that the US was the first prominent and potential destination for FDI from 2017 to 2019. This evidence provides the basis for further investment in the industrial sector of the economy, more specifically the chemical manufacturing industry, which contributes significantly to the GDP of the economy. The level of inward FDI flows into the US represents the country's preparedness to meet the technological demands of Industry 4.0 and it is a natural pathway for the workability and applicability of Industry 4.0 in the US economy as a whole. The development of ICTs and FDI in the context of the US economy is a signal of the inevitability of the much-expected revolution in the global economy.

5. Concluding remarks and policy recommendations

Although previous literature has investigated the role that air transport plays in economic growth, this study advances the exploration of air transport on economic growth under the TLGH framework by considering the relevance of Industry 4.0 in the US during the period 1981–2017. By filling this gap in the empirical literature, this study provides fresh evidence in the TLGH, considering coal rents, ICTs and FDI as additional explanatory variables. The empirical results, obtained from FMOLS, DOLS and CCR, confirm that investments in aviation infrastructure and support services are needed to enable sustainable strategic planning, providing an essential tool for the assessment of potential scenarios; where the tourism sector must be considered as the key to economic recovery and a critical factor in the development of the tourism sector. While the air transport industry makes a significant direct and indirect contribution to national income, the catalytic effects are evident in the US tourism sector. This contribution to GDP implies the necessity of studying the relationship between aviation and tourism. A limitation that has affected tourism growth is aviation industry policies, whether regulatory or not.

The significance of the econometric results also confirms that coal rents will enhance economic growth. This result contains implications for natural resources, while it is essential that more efficient energy strategies are included in the energy mix for the US. This objective of reducing fossil fuel sources implies greater government involvement in environmental issues, where the US administration would be well advised to become more engaged in international environmental agreements to reduce emissions. A new position that indicates progression towards a cleaner energy pattern that is less dependent on fossil sources would be perceived positively by tourists, who increasingly demand high-quality, low-pollution sustainable tourism.

Consequently, if the US aims to achieve higher economic growth from the tourism sector, this means that both government authorities and stakeholders must not only promote the level of investment in air transport infrastructures but also make a transition to more efficient energy sources that are less dependent on fossil sources, enabling sustainable growth. Since the existing literature does not bring the ICTs and FDI variables together; this study presents new evidence of how their combined relationship and the expansion of ICTs can modify FDI effects in the context of the exploration of economic growth. However, the expansion of manufacturing and high-tech business and this process does not provide unambiguous outcomes as the process is directly related to Industry 4.0. ICT seems to attract FDI since the availability of advanced infrastructure is an essential concern in the investment location decision-making process for foreign investors in the US, where the impact of the technologically-driven growth experienced in Industry 4.0 is premised upon the need to advance the living standards of the population.

Finally, the coming years will see more significant and broader changes in the global economy, especially as a result of the health crisis caused by the COVID-19 pandemic and its global effects. These effects will extend to the new economy and the new ICT revolution under the expansion of 5 G technology, the global effects of which are presently unpredictable in terms of economic growth, tourism and FDI inflows. However, under this new (post) COVID-19 context, these kinds of effects and their analysis will be necessary for policymakers as well as for managers in decision-making processes.

Credit (Contributor roles taxonomy)

As the corresponding author, I declare that all co-authors have contributed at the same level during the process of elaboration of this study.

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