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DIGITAL TECHNOLOGIES FOR IMPROVING LOGISTICS PERFORMANCE OF COUNTRIES

Aisulu Moldabekova[1, 2], Robert Philipp[3, 4], Hans-Eggert Reimers[4], Bauyrzhan Alikozhayev[1]

[1]Al Farabi Kazakh National University,
Al Farabi 71, 050040 Almaty, Kazakhstan
[2]Institute of Economics
Kurmangazy 29, 050010 Almaty, Kazakhstan
[3]TALTECH University
Ehitajate tee 5, 12616 Tallinn, Estonia
[4]Hochschule Wismar, University of Applied Sciences: Technology, Business and Design
Philipp-Müller-Str. 14, 23966 Wismar, Germany
kazsocium01@gmail.com
robert.philipp@hs-wismar.de
hans-eggert.reimers@hs-wismar.de
aliqozhaev.b@kaznu.kz

The logistics performance has a crucial role in the industrial and economic development of countries. This study aims to underline implications for policy makers in improving the logistics performance of countries in terms of Industry 4.0. For this purpose, the effect of digitalisation on logistics performance is analysed by using correlation and multiple regression analysis. The empirical study builds upon dimensions and indicators of the Digital Economy and Society Index (DESI) and Logistics Performance Index (LPI) of the World Bank. The results indicate that governmental policies should target to deliver sound framework conditions for the generation of human capital (here: ICT specialists), sustainable usage of internet services (e.g. professional social networks, online sales, etc.), integration of digital technologies (e.g. Big Data, Cloud computing, etc.), as well as digital connectivity (here: fixed broadband and 4G coverage) in order facilitate improvement of logistics performance.

Keywords: DESI, Digitalisation, Digital technologies, Industry 4.0, LPI

1. Introduction

Driven by novel technological trends, increasing global competition, and rapidly changing customer demands, organizations are forced to reconsider how they can take advantage from the upcoming digitalisation to better manage their supply chain activities (Marinagi *et al*., 2014). Further contemporary challenges of supply chains refer to growth and sustainability issues (e.g. climate and environmental aspects) as well as the construction of new and enlarged transport corridors or networks, respectively (e.g. Trans-European Transport Network – TEN-T, Silk Road 2.0, etc.) (Gerlitz *et al.*, 2018; Henesey & Philipp, 2019; Madjidian *et al.*, 2017; Philipp *et al.*, 2020a, 2019a & 2018). However, it is expected that especially disruptive innovations that arise in the context of Industry 4.0 influence most powerful efficiency in logistics and supply chains (e.g. Henesey & Philipp, 2019; Philipp, 2020a & b; Philipp *et al.*, 2020a & b, 2019b & c, 2018).

The Fourth Industrial Revolution (i.e. Industry 4.0) is the digital transformation in the manufacturing sector that becomes enabled by the application of numerous innovative digital technologies. Thus, Industry 4.0 is characterized by progressive connectivity, novel assistance systems and decentralized decision making. (Muhuri *et al*., 2019). The inherent digital technologies increase particularly responsiveness in case of fluctuations in demand as well as enhance flexibility regarding limited capacities. Next to this, the enabling technologies of the digital transformation heavily decrease lead times due to additive manufacturing and at the same time increase inventory control. (Ivanov *et al.*, 2019 & 2016).

The great potential and importance of digital technologies became apparent in the recent COVID-19 pandemic. Particularly, digital technologies play an active and crucial role in the provision of needed logistics and transport services. For instance, geographic information systems (GIS) and big data analytics

became important for balancing and managing supply and demand of limited material resources – e.g. medical supplies (Zhou *et al.*, 2020). Next to this, 'Digital supply chain twins' (i.e. the computerized supply chain models that represent the network state for any given moment in real time) are used to support decision-making during the epidemic outbreaks (Ivanov, 2020).

However, the digitisation of manufacturing processes in terms of Industry 4.0 require the interconnectivity and integration of the adjoining internal and external procedural landscape in order to ensure an efficient value creation. In this context, especially logistics receives high interest, since it has a crosscutting function and thus, affect all process-involved and dependent business units (Lai *et al*., 2010). Therefore, digitalisation of transport and logistics processes is generating considerable interest within Industry 4.0.

In the digitization era, transport systems and the provision of goods gain increasing significance in terms of mass adoption of smart and connected digital technologies and applications (e.g. cloud computing, big data analytics, machine learning, blockchain, Internet of Things – IoT), since they allow enhancing vertical and horizontal integration within supply chains (Kayikci, 2018). Particularly, IoT, cyber-physical systems as well as innovative products and services facilitate the development of smart supply chains (Ivanov *et al.*, 2019). Furthermore, digital technologies – such as blockchain and smart contracts – ease entrepreneurial collaborations of cross-organisational business-processes that are distinguishing for smart supply chains (Philipp *et al.*, 2019b & c).

In this context, the level of digital readiness becomes the main driver in the course of the aspired digital transformation of industries and economies. Previous studies analysed and examined the impact of digital technologies on logistics performance of companies (i.e. micro logistics level) (Kayikci, 2018; Lin & Ho, 2009) or on country level the relationship between competitiveness and logistics performance (Çemberci *et al*., 2015; Ekici *et al.*, 2019), trade and logistics performance (Gani, 2017), environment and logistic performance (Liu *et al.*, 2018) as well as incoterms clauses and logistics performance (Stojanović & Ivetić, 2020). Hence, building upon a comprehensive literature review, to the best of our knowledge, assessing the impact of digitalisation on logistics performance on country level (i.e. macro logistics level) has not been investigated so far, which represents a clear research gap.

The development of innovative digital technologies and the ever increasing use of information and communication techniques (ICT) in all branches of the economy have been one of the main priorities of manifold varying policies of the European Union (EU) for many years. For this reason, the EU provides comprehensive financial support for topic-related initiatives through different funding programmes that pursuit to achieve economic alignment among the heterogenic EU states. Accordingly, the EU is an interesting subject for studies, as its member states still demonstrate a great variety regarding the rate and level of economic development, dependence of their economies upon transport, and adoption of ICT in different sectors of the economy (Kos-ŁAbędowicz & Urbanek, 2017). Hence, there is a huge gap regarding the degree of digitalisation within the EU. (Cruz-Jesus *et al*., 2012; *Greco et al.*, 2019; Noussan & Tagliapietra, 2020). In this regard, the present study targets to investigate the link between the digital and logistics performance of the EU member states. Thus, the current study aims to empirically examine the effect of the digital performance on the logistics performance of European countries.

It is obvious that the effectiveness of logistics represents one of the main drivers for the economic development of countries and regions (e.g. Philipp *et al.*, 2020a). On the other hand, the examination of the contemporary fruitful prerequisites for the development of transport and logistics is relatively untacked. In this regard, and due to the fact that logistics has an important crosscutting function for the industry, it is worthwhile to study the influence of digitalisation on the effectiveness of logistics in order to promote economic growth. In response to this, the study in the further scientific discourse allows to identify implications to improve the efficiency of logistics using digital technologies on country level. At the same time, these aspects represent the major contributions of the present research.

The study is structured as follow: A literature review is provided in the following section, which is followed by a description of the data and methodology. Afterwards the results of the empirical analysis are set out. The paper rounds up with a conclusion, which includes implications for research and practice.

2. Literature review

The adoption and appropriate application of digital technologies within diverse logistics operations allows to achieve competitive advantages (Bhandari, 2014; Choy *et al.*, 2014). Starting from optimised resource planning and warehouse management systems over to intelligent transportation systems, digital technologies affect and support the logistics industry within manifold activities, whereby at the same time information and data security receives increasing significance (Barreto *et al.*, 2017; Kayikci, 2018; Oleśków-Szłapka & Stachowiak, 2018). Generally, digital technologies that are considered as

accelerators or facilitators for the digital transformation or Industry 4.0 in the manufacturing sector are labelled as enabling technologies. Hence, also in the context of the digital transformation concerning the logistics sector, current research efforts target to pinpoint innovative technologies that are expected to facilitate most powerful the digital transition. For instance, Harris *et al*. (2015) emphasize that the improvement of multimodal transportation increasingly depends on the smart application of enabling technologies such as cloud computing, wireless/mobile communication technologies and IoT. Similar findings were gathered by the study of Ardito *et al.* (2019), who aimed to identify enabling technologies pertaining to the fourth industrial revolution that can be considered as most relevant for an effective supply chain integration of firms – here: Industrial IoT, cloud computing, big data analytics, etc. Against this, Strange *et al.* (2017) assessed how the widespread adoption of digital enabling technologies – e.g. IoT, big data analytics, robotics, etc. – may affect the organisation of activities within global value chains.

More generally, Hofmann and Rüsch (2017) discussed the opportunities of Industry 4.0 in the context of logistics management. The authors highlighted that products and services have to be connected in a flexible manner via the internet or other network applications like the blockchain technology, which allow that value networks are controlled decentral. They present evidence that the digital connectivity has the potential to enable an automated and self-optimized production of goods and services including the delivery without human interventions – i.e. self-adapting production systems based on transparency and predictive analytics. Witkowski (2017) underlines that especially IoT is important for the logistics and transport sector, as the integration of respective solutions deliver operational data about the location and condition of things. With such information, it is possible to improve services and thus, customer satisfaction by shortening the costs due to reduced cycles of logistics processes (ibid.). In a similar way, Barreto *et al*. (2017) stress that IoT is able to tackle major challenges in logistics, like transparency issues (supply chain visibility) or integrity control in supply chains – right products at the right time, place, quantity and costs. Other researchers like Liu *et al.* (2019) take one step further and suggest individual use cases, like an IoT enabled real-time status sensing model for logistics vehicles for improved logistics services, which facilitates the reduction of logistics costs through optimised fuel consumption and improved utilization rate.

Another group of researchers investigated how digital technologies increase the quality level of logistics services. For instance, Evangelista *et al.* (2012) investigated novel technology applications in relation to customer acceptance and perception of quality and satisfaction regarding logistics services. Their findings indicate that both logistics service quality perception and satisfaction level are significantly related to future purchase intentions and the usage of information technologies (Bienstock *et al.*, 2010 & 2008). A similar study from Murfield *et al.* (2017) investigated the impact of logistics service quality on consumer satisfaction and loyalty in an omni-channel retail environment. Their results show that all three dimensions of logistics service quality (i.e. condition, availability and timeliness) are distinct in their impact on customer satisfaction and loyalty.

By summarising the findings from the conducted literature review, on company level (i.e. micro logistics level), several studies analysed the impact of different digital technologies on logistics performance. Hence, it can be stated that different IT applications provide a sustainable mean for firms to improve their logistics performance (Lai *et al.*, 2010). For instance, next to the abovementioned examples, further studies showcased a positive association between the willingness to adopt RFID technology and supply chain performance in case of logistics service providers (Lin & Ho, 2009). Vice versa, it was also discussed in recent studies that from a holistic perspective the digitisation of the entire performance process of firms comprising planning, procurement, manufacturing, delivering and return will further result in improved logistics processes with optimized workflows and reduced lead times (e.g. Kayikci, 2018). Although there exist several scientific studies that focused on the effects from digital efforts on logistics performance on micro level, there is a lack of research studies that focalised on the relationship between digital and logistics performance on macro level. Hence, deeply rooted in the fact that the digital readiness of a country may be regarded as one of the crucial determining factors for the success and efficiency of the digital transformation in companies or even entire industries, the great importance becomes evident to investigate the relationship between the digitalisation level and the efficiency of logistics performances on national level. Accordingly, these rationales lead to the following research questions:

- What is the relationship between the digital performance and logistics performance of countries?
- What are the crucial aspects or factors of the digitalisation that have a significant impact on the logistics performance of countries?

3. Data and Methodology

The aim of the research is to identify the digitalisation affect to a country's logistics performance. The digitisation level or digital readiness of a country as well as the respective logistics performance are examined by different indices. Hence, the digital economy and society index (DESI) and the logistics performance index

(LPI) are chosen for the current analysis. The DESI (database: 2014-2018) is published by the European Commission and evaluates the factors that collectively determine the digital readiness of a country – calculated as the weighted average of the five main dimensions: connectivity, human capital, use of internet services, integration of digital technology and digital public services. Against this, the LPI (database: 2007-2018) is published by the World Bank in order to measure countries' logistics performance (Arvis et al., 2018). Hence, this index ensures to get a reasonable understanding of achievements in logistics on national level for a wide range of countries around the world. These indices represent a composite indicator that can be extracted for an independent evaluation using correlation and linear regression analysis (see Table 1).

Table 1. Methods of analysis and studied aspects based on DESI and LPI indexes

No.	Method of analysis	Studied aspect
1.	Correlation	The Pearson's correlation is used to study the relationship between the digitalisation level and logistics performance of countries (dimensions of DESI and LPI)
2.	Liner regression	The pooled regression is used to identify the digitalisation activities, which may impact the logistics performance of countries (sub-dimensions of DESI and LPI)

The study sample embraces 28 countries of the European Union, the analysed data set covers the annual data form 2014 to 2018. Variables for the current study are connectivity (DESI-C), human capital (DESI-H), use of internet services (DESI-I), integration of digital technology (DESI-T), digital public services (DESI-P), overall LPI (LPI-O), customs (LPI-C), infrastructure (LPI-I), international shipments (LPI-S), logistics quality and competence (LPI-QC), tracking and tracing (LPI-TT) and timeliness (LPI-T). The details for the variables are given in Table 2. Furthermore, the descriptive statistics or country-specific variables are shown in the Appendix 1 and 2.

Table 2. Variables of DESI and LPI

No.	Variables	Description
1.1	Connectivity (DESI-C)	DESI connectivity dimension calculated as the weighted average of the five sub-dimensions: 1a fixed broadband (18.5%), 1b mobile broadband (35%), 1c fast broadband (18.5%), 1d ultrafast broadband (18.5%) and 1e broadband price index (9.5%)
1.2	Human Capital (DESI-H)	DESI human capital dimension calculated as the weighted average of the two sub-dimensions: 2a internet user skills (50%) and 2b advanced skills and development (50%)
1.3	Use of Internet Services (DESI-I)	DESI use of internet dimension calculated as the weighted average of the three sub-dimensions: 3a internet use (25%), 3b activities online (50%), 3c transactions (25%)
1.4	Integration of Digital Technology (DESI-T)	DESI integration of digital technology dimension calculated as the weighted average of the two sub-dimensions: 4a business digitisation (60%) and 4b e-commerce (40%)
1.5	Digital Public Services (DESI-P)	DESI digital public services dimension calculated as the weighted average of the two sub-dimensions: 5a e-government (80%) and 5b e-health (20%)
2.	Overall LPI (LPI-O)	Logistics performance index examines the ease of supplying goods and the state of trade logistics at the national and international levels.
2.1	Customs (LPI-C)	The sub-index customs represents an indicator for the efficiency of customs clearance processes.
2.2	Infrastructure (LPI-I)	The sub-index infrastructure represents an indicator for the quality of trade and transport-related infrastructure.
2.3	International shipments (LPI-Sh)	The sub-index international shipments represents an indicator for the ease of arranging competitively priced shipments.
2.4	Logistics quality and competence (LPI-QC)	The sub-index logistics quality and competence represents an indicator for the competence and quality of logistics services.
2.5	Tracking and tracing (LPI-TT)	The sub-index tracking and tracing represents an indicator for the ability to track and trace consignments.
2.6	Timeliness (LPI-T)	The sub-index timeliness represents an indicator for the frequency with which shipments reach consignee within scheduled or expected time.

Source: Compiled by authors, based on: European Commission (n.d.) and World Bank (n.d.)

The variables concerning DESI represent the indicators for the digital readiness of countries and thus, are the basic conditions for the formation of the digital economy. These variables are the explanatory variables. The endogenous variables are the LPI-variables. In the regression analysis missing values for variables (i.e. 4G Coverage, big data, and cloud) had been replaced by arithmetic means. The data for one year was displaced to increase the number of observations for the statistical analysis.

To reveal the effects of digitalisation on logistics performance the pooled regression approach is selected. The usual linear model could be described as:

$$Y_{it} = B_1 + B_2 \cdot X_{1,it} + B_3 \cdot X_{2,it} + \ldots + u_{it}\,, \quad (1)$$

where Y_{it} is the endogenous variable, $X_{j,it}$ are the explanatory variables, B_j are the coefficients and B_1 present the intercept term. The country index is i and the time index is t.

4. Results

In the frame of the conducted study, in a first step, the relationship between the dimensions of DESI and LPI is analysed using Pearson's correlation. Results show the high positive relationship between the dimensions of DESI and LPI-O (0.503-0.572) – by neglecting the dimension digital public services (DESI-P) (0.384). The sub-indicators of LPI, such as customs (LPI-C), infrastructure (LPI-I), logistics competence and quality (LPI-CQ) have high positive correlation with connectivity (DESI-C), human capital (DESI-H), use of internet (DESI-I), as well as integration of digital technology (DESI-T) (0.498-0.652) (cf. Table 3).

Table 3. Correlations between variables of LPI and DESI

	DESI-C	DESI-H	DESI-I	DESI-T	DESI-P
LPI-O	.523**	.572**	.572**	.503**	.384**
LPI-C	.543**	.652**	.648**	.546**	.464**
LPI-I	.498**	.599**	.604**	.514**	.379**
LPI-Sh	.499**	.447**	.448**	.400**	.316**
LPI-CQ	.520**	.574**	.574**	.518**	.389**
LPI-TT	.458**	.494**	.489**	.464**	.333**
LPI-T	.431**	.442**	.447**	.380**	.269**

** Correlation is significant at the 0.01 level (2-tailed)

Furthermore, a multiple regression was run to model LPI on DESI dimensions. Variables that increase the probability of F by at least 0.05 were included and by less than 0.1 were excluded in SPSS regression linear procedure (Analyze – General linear models – Univariate Analysis). Overall the estimated coefficients are small, but significantly positive. An increase of the DESI variables raises the logistic performance indicator. In detail, these results highlight that connectivity (DESI-C) and integration of digital technology (DESI-T) effect the overall LPI (LPI-O) (cf. Table 4).

Table 4. Results of regression analysis of LPI and DESI dimensions

Parameter	B	Std. error	t	Sig.
Intercept	2.156	0.193	11.173	0.000
DESI-C	0.056	0.021	2.652	0.009
DESI-H	0.020	0.025	0.816	0.416
DESI-I	0.010	0.047	0.211	0.833
DESI-T	0.045	0.019	2.354	0.020
DESI-P	-0.002	0.018	-0.122	0.903

R Squared = 0.434 (Adjusted R Squared = 0.390)
F = 12.904 (Sig. = 0.000)
Dependent Variable: LPI-O. GLM: (Intercept), DESI-C, DESI-H, DESI-I, DESI-T, DESI-P

It is worth noting that the evidence of the correlation and regression analysis show that the digital public services (DESI-P) did not have a particular effect on the overall and LPI indicators. As a result, individual indicators of this dimension are not included for further analysis, since the sub-dimensions of this criteria are not relevant for the research purpose. However, impacts of sub-criteria from connectivity (DESI-C), human capital (DESI-H), use of internet services (DESI-I), integration of digital technology (DESI-T) on LPI indicators are evaluated.

To tackle the detail analysis, the DESI indicators are split up into their baseline variables. The individual indicators of each DESI-dimension are given in Appendix 2. This analysis allows to determine variables, which may be changed by economic policy of a country. Repeating the procedure of general linear model, the following results are obtained (see Table 5). Overall LPI (PPI-O) is determined by the following indicators of the sub-dimension connectivity (DESI-C): fixed broadband coverage (1a1), 4G coverage (1b1) and broadband price index (1e1).

Table 5. Results of regression analysis of LPI and indicators of DESI sub-dimension connectivity

Parameter	B	Std. error	t	Sig.
Intercept	-0.579	0.587	-0.986	0.330
1a1	0.020	0.006	3.067	0.004
1a2	0,002	0.004	0.549	0.586
1b1	0.017	0.003	5.557	0.000
1b2	-0.001	0.001	-0.752	0.456
1c2	0.003	0.004	0.652	0.518
1d2	-0.004	0.007	-0.576	0.568
1e1	0.009	0.003	3.162	0.003

R Squared = 0.662 (Adjusted R Squared = 0.608)
F = 12.288 (Sig. = 0.000)
Dependent Variable: LPI-O. GLM: (Intercept), 1a1, 1a2, 1b1, 1b2, 1c2, 1d2, 1e1

It is noticeable that the indicator ICT specialists (2b1) in the DESI sub-dimension human capital (DESI-H) plays a main role in improving logistics performance (cf. Table 6).

Table 6. Results of regression analysis of LPI and indicators of DESI sub-dimension human capital

Parameter	B	Std. error	t	Sig.
Intercept	2.919	0.084	34.779	0.000
2b1	0.222	0.037	5.954	0.000
2b2	-0.038	0.070	-0.535	0.594

R Squared = 0.418 (Adjusted R Squared = 0.407)
F = 38.39 (Sig. = 0.000)
Dependent Variable: LPI-O. GLM: (Intercept), 2b1, 2b2

Logistics Performance (LPI-O) is established by the following indicators of the sub-dimension use of internet services (DESI-I): news (3b1), video calls (3b4), social networks (3b5), professional social networks (3b6), shopping (3c2) and selling online (3c3) (cf. Table 7).

Table 7. Results of regression analysis of LPI and indicators of DESI sub-dimension use of internet services

Parameter	B	Std. error	t	Sig.
Intercept	4.308	1.207	3.571	0.001
3a1	-0.012	0.016	-0.764	0.447
3a2	0.001	0.015	0.095	0.925
3b1	-0.005	0.003	-1.853	0.067
3b4	-0.005	0.003	-1.841	0.069
3b5	-0.008	0.004	-2.153	0.034
3b6	0.019	0.006	3.001	0.003
3b7	0.012	0.009	1.429	0.157
3b8	-0.004	0.007	-0.579	0.564
3c1	-0.003	0.002	-1.504	0.136
3c2	0.007	0.004	1.792	0.076
3c3	-0.005	0.003	-1.869	0.065

R Squared = 0.681 (Adjusted R Squared = 0.643)
F = 17.68 (Sig. = 0.000)
Dependent Variable: LPI-O. GLM: (Intercept), 3a1, 3a2, 3b1, 3b4, 3b5, 3b6, 3b7, 3b8, 3c1, 3c2, 3c3

Moreover, the indicators of the sub-dimension integration of digital technology (DESI-T), social media (4a2), big data (4a3), e-Commerce turnover (4b2) and selling online cross-border (4b3) are key parameters in improving logistics performance (cf. Table 8).

Table 8. Results of regression analysis of LPI and indicators of DESI sub-dimension integration of digital technology

Parameter	B	Std. error	t	Sig.
Intercept	2.356	0.211	11.143	0.000
4a1	-0.011	0.011	-1.044	0.314
4a2	0.033	0.015	2.140	0.050
4a3	0.076	0.029	2.567	0.022
4a4	-0.012	0.014	-0.838	0.416
4b1	0.000	0.028	-0.004	0.997
4b2	0.102	0.029	3.561	0.003
4b3	-0.071	0.027	-2.629	0.020

R Squared = 0.794 (Adjusted R Squared = 0.691)
F = 7.722 (Sig. = 0.001)
Dependent Variable: LPI-O. GLM: (Intercept), 4a1, 4a2, 4a3, 4a4, 4b1, 4b2, 4b3

Furthermore, the detailed analysis found the following evidence for the sub-indexes of the LPI:

- customs (LPI-C) is determined by integration of digital technology (DESI-T) components: electronic information sharing (4a1), SMEs selling online (4b1), cloud (4a4); as well as by human capital (DESI-H) component: ICT specialists (2b1);
- infrastructure (LPI-I) is determined by use of internet services (DESI-I) components: shopping (3c2), professional social networks (3b6); as well as integration of digital technology (DESI-T) components: SMEs selling online (4b1), electronic information sharing (4a1), selling online cross-border (4b3);
- international shipment (LPI-Sh) is determined by connectivity (DESI-C) components: fixed broadband coverage (1a1), 4G coverage (1b1) and broadband price index (1e1);

- logistics competence and quality (LPI-CQ) is determined by use of internet services (DESI-I) component: professional social networks (3b6); as well as by integration of digital technology (DESI-T) components: electronic information sharing (4a1), SMEs selling online (4b1);
- tracking and tracing (LPI-TT) is determined by integration of digital technology (DESI-T) components: electronic information sharing (4a1), SMEs selling online (4b1); as well as by human capital (DESI-H) component: ICT specialists (2b1);
- timeliness (LPI-T) is determined by use of internet services (DESI-I) components: shopping (3c2) and professional social networks (3b6).

It is important to note that all estimated coefficients are positive. An increase of the pinpointed DESI indicators raises the performance of the corresponding logistic performance dimension.

To sum up, according to the results it is apparent that the logistics performance can be improved by measures that target to enhance the digital performance of countries. In reflection of all findings, it can be stated that all indicators of the sub-dimension integration of digital technologies (DESI-T) have an significant impact on the logistics performance of a country – i.e. electronic information sharing (4a1), social media (4a2), big data (4a3), cloud (4a4), SMEs selling online (4b1), e-Commerce (4b2), selling online cross-border (4b3). Furthermore, enhancements in case of indicators concerning the sub-dimension use of internet services (DESI-I) have also an effect on the logistics performance of a country – particularly news (3b1), video calls (3b4), social networks (3b5), professional social networks (3b6), shopping (3c2) and selling online (3c3). A further interesting finding is that human capital (DESI-H) that is associated with high digital knowledge, skills and capabilities (i.e. here: ICT specialists – 2b1) is one of the main resources and drivers for the enhancement of logistics performance. Furthermore, the findings confirm that fixed broadband coverage (1a1) and 4G coverage (1b1) as well as broadband price index (1e1) have a positive influence on countries' logistics performance.

5. Discussion and conclusion

In this study, empirical evidence is presented that the digitalisation degree of EU countries is the source for the formation and development of logistics performance of economies. As shown in the study, specific digitalisation factors significantly affect the parameters of logistics performance of countries. The implementation of Industry 4.0 elements in logistics processes requires a high level of technological and digital readiness. This is detected and derived from the EU countries and their respective performance in the two indices (i.e. DESI and LPI). Accordingly, in a wider sense, integration of digital technologies and use of internet services predetermine the effectiveness of logistics and the efficiency of logistics services. Moreover, the results also reveal that governmental policies have to focus on the delivery of sound basic conditions for the digital transformation of the economy and society in form of human capital (specifically: ICT knowledge). Furthermore, the governments should push ahead the digital connectivity by fostering the fixed broadband and 4G coverage in order to enhance the national logistics performance.

By zooming out and having a holistic view on the findings, this study makes it possible to comprehensively uncover the picture of the level of digital readiness and logistics performance in the context of countries and their respective development. The findings show that the digital readiness of a country is positively and statistically significantly correlated with the logistics performance of the country. Therefore, the overall main policy implication can be seen in the fact that continuous investments in digitalisation enhance the logistics performance of countries. In this regard, it is necessary to introduce new digital solutions into the activities of logistics service providers to improve the logistics performance of countries. The managerial implications for strengthening logistics performance rates via current technologies are: integrate information systems in providing logistics services; appropriate decision making in case of ICT and digital technologies for planning and scheduling of logistics activities; automate processes and operations (loading/unloading, warehousing, ordering, delivering, etc.); develop and introduce omni-channel logistics; enhance communication and develop closer links concerning clients and suppliers; as well as acquire quality management skills through training and education. To sum up, especially the appropriate integration and usage of the digital technologies for increasing logistics performance may gain competitive advantages that fosters the development of economies.

The central limitation can be seen in the lack of data for some years. Hence, some sub-dimensions of the DESI (i.e. 5G readiness, NGA coverage, ultrafast broadband coverage, and at least basic digital skills, above basic digital skills, at least basic software skills, ICT graduates, music, videos and games, video on demand) were excluded from the analysis due to the lack of data for some years as well as limited relevance for the indicated research objective. Regarding further research activities, future studies should target to investigate more in-depth the different enabling technologies of Industry 4.0 that are not included in the DESI by comparing different countries. Furthermore, it would be worthy to compare different logistic companies and their level of digitalisation in relation to their operative performance.

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Appendix

1. Descriptive Statistics of DESI and LPI dimensions

	N	Minimum	Maximum	Mean	Std. deviation
Connectivity (DESI-C)	112	5	17	11.3	2.8
Human Capital (DESI-H)	112	6	19	10.9	3.0
Use of Internet Services (DESI-I)	112	2	10	6.3	1.8
Integration of Digital Technology (DESI-T)	112	3	12	6.4	2.2
Digital Public Services (DESI-P)	112	3	11	7.1	2.3
Overall LPI (LPI-O)	112	2.78	4.23	3.5	0.4
Customs (LPI-C)	112	2.38	4.12	3.4	0.4
Infrastructure (LPI-I)	112	2.35	4.44	3.5	0.5
International Shipments (LPI-Sh)	112	2.69	4.24	3.4	0.3
Logistics Quality and Competence (LPI-QC)	112	2.64	4.31	3.5	0.5
Tracking and Tracing (LPI-TT)	112	2.54	4.38	3.6	0.5
Timeliness (LPI-T)	112	2.88	4.80	3.9	0.4

2. Descriptive Statistics of variables from the sub-dimensions of the DESI

	N	Minimum	Maximum	Mean	Std. deviation
Connectivity (DESI-C)					
1a1 Fixed Broadband Coverage	112	79	100	94.8	5.5
1a2 Fixed Broadband Take-up, by All Households	110	50	97	68.9	10.6
1b1 4G Coverage, by Total	56	44	99	88.2	11.3
1b2 Mobile Broadband Take-up, by Total	112	25	145	72.4	25.9
1c2 Fast Broadband take-up, by All Households	109	0	72	24.3	16.8
1d2 Ultrafast Broadband Take-up, by All Households	109	0	47	9.1	10.4
1e1 Broadband Price Index, by Broadband Price Index	108	16	95	78.3	14.7
Integration of Digital Technology (DESI-T)					
4a1 Electronic Information Sharing	109	8	53	30.8	10.0
4a2 Social Media	108	5	42	16.9	8.3
4a3 Big Data	50	2	19	10.5	4.0
4a4 Cloud	59	2	48	12.5	9.4
4b1 SMEs Selling Online, by SMEs (10-249 persons employed), without Financial Sector	110	4	31	14.5	6.5
4b2 e-Commerce Turnover, by SMEs (10-249 persons employed), without Financial Sector	93	1	22	8.5	4.2
4b3 Selling Online Cross-Border, by SMEs (10-249 persons employed), without Financial Sector	110	1	16	7.1	3.2
Human Capital (DESI-H)					
2b1 ICT Specialists	112	1	6	2.9	1.3
2b2 Female ICT Specialists	110	0	3	0.7	0.7
Use of Internet Services (DESI-I)					
3a1 People who never used the Internet, by All Individuals (age 16-74)	112	2	42	17.4	10.3
3a2 Internet Users, by All Individuals (age 16-74)	111	45	96	75.1	12.1
3b1 News, by All Individuals (age 16-74)	108	41	94	74.3	12.7
3b4 Video Calls, by All Individuals (age 16-74)	111	20	85	44.8	13.2
3b5 Social Networks, by All Individuals (age 16-74)	111	44	87	64.8	9.2
3b6 Professional Social Networks, by All Individuals (age 16-74)	112	3	35	12.3	6.7
3b7 Doing an Online Course, by All Individuals (age 16-74)	110	3	18	6.7	3.4
3b8 Online Consultations and Voting, by All Individuals (age 16-74)	112	2	32	8.8	4.9
3c1 Banking, by All Individuals (age 16-74)	112	7	93	57.3	23.0
3c2 Shopping, by All Individuals (age 16-74)	111	15	87	56.4	18.2
3c3 Selling Online, by All Individuals (age 16-74)	112	1	50	18.9	11.1