DIGITALIZATION IMPACT ON LOGISTICS EFFICIENCY OF SUPPLY CHAIN

by

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LIST OF ABBREVIATIONS

WB. World Bank

IMF. International Monetary Fund

OLS. Ordinary least squares

SC. Supply chain

GDP. Gross domestic product

DAI. Digital performance index

LPI. Logistics performance index

Chapter 1. INTRODUCTION

The global economy is in a process of digital transformation. Thus, it becomes obvious that digital technologies play a key role in supply chain.

Nowadays companies overcome the active application of digital technologies, and for them, it is crucial to have a full understanding of the list of benefits they can obtain by digital adoption. There is always room for improvement that digital technologies implementation can offer. And the influence of technologies can be clearer in the industry.

Logistics is a key to safe, effective planning and coordination of products' movement. It can both ensure the availability of products and improve merchandise. Established partnerships with businesses which offer transportation and warehousing services can offer a possibility for business leaders to reduce their costs.

Due to the global growth of trade and thus growth of customer demand, it is crucial for business to constantly evolve to ensure high performance and better results. These days customers tend to impulse shop using a smartphone and their expectations about receiving their orders timely are higher. Professionally organised logistics enable businesses to meet such requirements.

Digitalization transforms the traditional approach to supervising data and its collection, which is mostly manual and prone to human error or delay. It is making routine-like processes of the supply chain automized. Digitally improved logistics allow organisations to save money on operating expenses, enhance productivity and make order fulfilment more accurate. Vendors and partners also benefit from increased data transparency. Stakeholders obtain improved access to information, through integrated logistics applications which communicate and collaborate via a centralised information system, thus correcting their decision-making process.

The adoption of digital methods by supply chain companies enhances distribution processes, warehouse management and fulfilment data. Not only it gives a possibility to automate carrier operations but also increases the efficiency of labour management and employee engagement. Data-informed decisions can be reached by implementing logistics platforms that incorporate elements of machine learning.

Digitalization of supply chains and logistics in particular is a dynamic process of acquiring new technologies that are integrated across various operations with the purpose of improving the efficiency of the companies and organisations involved. It is believed that digital capabilities are widely used in the areas of transportation, preparations of orders, as well as storage and other logistics services.

The integration of Industry 4.0 technologies has brought about a paradigm shift in supply chain processes, resulting in a transformation that offers significant benefits to global market players. This transformation empowers them with enhanced collaboration capabilities within complex multi-layered systems, as highlighted in a report by American Express (2022). The adoption of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, and Robotics has led to improved visibility, traceability, and decision-making across the supply chain network. These advancements have resulted in reduced lead times, optimized inventory management, and improved customer service levels, making the supply chain more efficient and competitive in the global market.

This study aims to present an extensive review that should explain and prioritise the available knowledge on digital transformation in supply chain factors. It summarizes the existing studies to explain the current conditions of the art in supply chain transformation. This review should highlight the most important topics and present the possible trends in this fast-growing sector.

We study the articles published in Web of Science and Scopus databases as well as on other resources and use statistical modelling on the countries' data. Using R studio, statistical analysis of 153 countries with observations for several years is analyzed.

The study indicates the most important topics that are frequently appearing in the literature. Among them are "sustainable supply chain management" and "circular economy and industry 4.0 technologies". The list of the most discussed technologies that are applied to the supply chain include blockchain, artificial intelligence, machine learning, predictive maintenance, the Internet of Things, and big data. Though the list is not exhaustive, the list introduced above will be further presented in more detail.

Digital transformation has introduced a new perspective on business operations, offering opportunities to meet the ever-growing demand in today's dynamic business environment. Businesses are leveraging Industry 4.0 technologies as part of their digital transformation journey to enable seamless integration of systems and processes. Supply chain management is concerned with cost reduction and the development of responsive flexible, integrated systems that allow conducting sufficient management to adapt to constant changes in consumer behaviour. Organizations can be supported with digital transformation in generating innovations, enhancement of product development and improved flexibility.

Globally digital transformation utilizes freshly adopted technologies in various sectors to enable Industry 4.0 for manufacturers, service providers, governments, and the final consumer. This results in synchronised production, mitigation of information distortion and reduced time for delivery.

Industry 4.0 is known to automatically adjust responsive production lines for corresponding types of products adapting to conditions that continuously change. It enables both customized goods and rational resource consumption due to productivity and flexibility.

Digitalization in logistics plays the leading role in shaping supply chain management and transforming processes, that define the supply chain ecosystem. An ideal digital supply chain (DSC) provides efficient electronic delivery of products from the starting point (producer) to the target point (final consumer). DSC wisely utilizes new technologies to build a transparent, flexible, and reliable supply chain management system. Technologies associated with digital supply chains serve firms as a tool to meet demanding customer's needs timely.

Cutting-edge technologies at the core of digital transformation, such as the Industrial Internet of Things (IoT), cyber-physical systems (CPS), and machine learning, are elevating supply chain performance to unprecedented heights, bridging the gap between the physical and digital realms.

Industry 4.0 inevitably changes the SC approach towards targeting smarter and more flexible processes, increased automation, rational and efficient resource planning.

The main goal of this study is to clarify the reasons for the growth of supply chain performance efficiency across countries. What were the drivers of the success of logistics chains? What was more important: digital adoption of technologies or factors like policies, administrative management or transportation infrastructure? Or maybe all mentioned above were equally important measures.

The impact of the digital adoption index on the logistics performance index was estimated using firstly OLS regression model. The model was also controlling for variables relating to the logistics performance dataset such as ease of arranging competitively priced international shipments, the efficiency of the clearance process, frequency of shipments reaching consignee within scheduled or expected time.

In general, empirical evidence supports the existence of dependence between the digitalization measured in our case by digital adoption index and the quality of logistics

services. To be more precise this study's results confirmed a positive relationship between them.

The topic of Digitalization Impact on Logistics Efficiency of Supply Chain is highly relevant in today's rapidly evolving business environment. With the increasing adoption of digital technologies, there is a growing need to understand how digitalization affects logistics efficiency within the supply chain, and ultimately impacts economic performance at a country level.

The relevance of this topic can be seen from multiple perspectives:

1. Business and Industry: The digitalization of logistics has the potential to significantly impact the efficiency and effectiveness of supply chain operations, leading to improvements in cost savings, reduced lead times, enhanced visibility, and increased customer satisfaction. Understanding the impact of digitalization on logistics efficiency can help businesses make informed decisions about their supply chain strategies, investments in technology, and operational processes to stay competitive in the digital era.
2. Government and Policy: Governments play a critical role in shaping the environment for logistics and supply chain operations through policies and investments in transportation infrastructure, digital technologies, and regulatory frameworks. Analyzing government expenditures on transport and its impact on logistics efficiency, along with digital adoption index, can provide insights for policymakers to formulate effective strategies for promoting digitalization in logistics, improving national logistics performance, and stimulating economic growth.
3. Academia and Research: The topic of digitalization and logistics efficiency within the supply chain is an emerging research area with significant scope for academic inquiry. Analyzing country-level data on logistics performance index, GDP,

government expenditures on transport, and digital adoption index can contribute to the existing body of knowledge on supply chain management, logistics, and digital transformation. The research findings can provide valuable insights, empirical evidence, and theoretical frameworks that can be used by researchers, scholars, and students for further studies and discussions.

The paper is organized as follows: chapter 2 provides a literature overview, and main discussed theories; chapter 3 describes the methodology, data collection process and state research hypotheses; chapter 4 presents data overview; chapter 5 describes the results of the analysis and chapter 6 completes with conclusions and recommendations.

Chapter 2. LITERATURE REVIEW

We are now living in the era of digitalization which implies changes for individuals, businesses, and governments. The theoretical and empirical literature on the relationship between digital inclusion and the quality of supply chains is quite extensive. Despite the numerous studies, evidence of digital contribution to supply chain efficiency is still scarce. That is why in this chapter we will examine literature with subsections in the following order: supply chain theory, digitalization, and other factors that affect supply chain efficiency.

2.1 Supply chain theory

A supply chain encompasses the interconnected relationships between a company and its suppliers, with the aim of producing and distributing a particular product to the end consumer. This system comprises diverse activities, individuals, entities, information, and resources, and encompasses the steps involved in transforming the product or service from its initial state to the ultimate buyer.

In addition to the different types and complexities of supply chains, there are also various supply chain management strategies and theories that have been developed over time. One such theory is the concept of supply chain integration, which emphasizes the importance of collaboration and coordination among different entities in the supply chain in order to improve overall efficiency and effectiveness. The aspects of the supply chain comprise the production and delivery process including the activities that are seen at each stage. It combines information flows and natural resources and transfers them into useful materials. Adds human resources and other components which transmute to final goods and services. Aggregation of SC roadmaps is one of the key steps to performing external analysis in a process of strategic planning.

PwC (2016) in the report that describes the ideas that make the supply chain more agile and more customer-oriented states that supply chains operate along the traditional

scheme of supply chain management, named SCOR1, which has a unique framework for linking business process, performance metrics and best practices. Each of these elements is subject to structural changes due to the rapid diffusion of innovative technologies. The SCOR model, or the Supply Chain Operations Reference model, was developed by the Supply Chain Council as a framework for evaluating and improving supply chain processes. It is a widely-used model in supply chain management, providing a common language and standard for businesses to analyze and improve their supply chain practices.

The SCOR model consists of five levels of process improvement: process, component, sub-process, activity, and task. The overarching model categorizes the five fundamental processes of the supply chain as planning, sourcing, manufacturing, delivering, and managing returns. These processes encompass the entire supply chain from the initial planning and sourcing of materials to the delivery of finished products and the management of customer returns.

In addition, the SCOR model includes an enabling process, which supports the other processes through the use of technology, human resources, and other resources. This includes functions such as finance, human resources, and IT support. Each of these processes is broken down further into sub-processes and activities, allowing businesses to identify specific areas for improvement and optimization. By using the SCOR model, businesses can evaluate their supply chain practices and compare them to industry best practices, allowing them to identify areas for improvement.

Supply chain complexity is an important concept to consider when analyzing the effectiveness and efficiency of a supply chain. As outlined by Mason and Omar (2018), there are three types of supply chain complexity: direct, extended, and ultimate.

Direct supply chains involve a company, supplier, and customer, all of whom are involved in the upstream and/or downstream flows of products or services. In other words, a direct supply chain entails the immediate entities that are directly engaged in the production and distribution of goods or services.

Extended supply chains involve the links between the suppliers of the immediate supplier and the customers of the immediate customer. This means that an extended supply chain includes entities that are further removed from the direct supply chain but still play a role in the overall production and distribution of goods or services.

Finally, ultimate supply chains encompass all organizations that are involved in all upstream and downstream flows from the ultimate supplier to the ultimate customer. This type of supply chain is the most complex and includes all entities that are involved in the entire supply chain process, from the very beginning of production to the final delivery of goods or services to the end customer.

PLEX (2019) classifies SC types as short and long supply legs. Short supply legs providers offer small quantities, and they are using just in time planning approach allowing them to deliver goods often within the same day. Key players are either local or regional suppliers. Opposed to it long legs consist of global international suppliers. It is where logistics plays a very important role.

Blume Global (2018) outlines in their research on supply chain ecosystems the typical steps involved in sourcing, transporting, manufacturing, or distributing products, which are commonly followed by the majority of organizations. The first step includes active supply chain management – such as determining necessary raw materials and matching them with manufacturing needs and sending them after to manufacturers. After raw materials are received and constructed into the parts - they are transferred into intermodal shipping containers where it is picked up by an intermodal marketing company and transferred to the terminal. Then, the carrier or forwarder transports the goods overseas and passes it to a logistics service provider (LSP) which loads them onto trucks leased from an equipment provider. In turn, shipper/beneficial cargo owner (BCO) stores them in its warehouses before the final distribution to customers.

To make sure that the whole ecosystem works efficiently common metrics are used so that potential weaknesses can be distinguished and eliminated. In order to identify

a competitive supply chain comparison of performance measures is utilised. Qualitative type of performance measures is that, which objectively cannot be numerically defined (such as customer satisfaction, product quality, SC vulnerability, SC resilience). George and Pillai (2019) suggest that indicators such as fill rates, costs, inventory levels, and resource utilization can be directly measured, making them quantitative in nature. Authors defined in their research fill rate as a ratio in a lost sale environment between the demand satisfied and the demand occurred. The fill rate indicates the product service level. George and Pillai also introduce the term inventory variance. It is a numerical measure that displays the fluctuations in actual inventory within some period. With increased inventory variance holding and shortage costs also increase.

Chiu (2020) also employs these metrics to assess the performance of supply chains. He adds that knowing the fill rate is important because it gives an idea about when the sales that can be recovered or serviced better if inventory performance is improved. But unlike previous authors, he uses an inventory turnover indicator as opposed to inventory variance as a representative metric for inventory management efficiency. According to the author, it provides a precise, comprehensive image of the effectiveness of the entire supply chain system. Different companies use different inventory turnover benchmarks which may differ significantly among them. A grocery store might update inventory 20 times per year, whereas industry turnover for computer equipment might be 6 times per year. As a rule, a low inventory turnover compared to the company's sector implies that a company faces excess inventory mostly due to weak sales. Elimination of the breaches in inventory turnover metric, according to Chiu leads to stronger sales and an agile, efficient process.

2.2 Digitalization and other factors affecting supply chain performance

Digitalization has brought about a notable impact on supply chain performance, with the introduction of cutting-edge technologies such as the Internet of Things (IoT),

blockchain, and artificial intelligence (AI). These technologies enable real-time tracking of goods, automation of processes, and data analytics for informed decision-making. As a result, supply chain visibility, efficiency, and responsiveness to customer demands have been significantly enhanced, leading to reduced lead times and costs.

In addition to digitalization, other factors affecting supply chain performance include globalization, which has led to longer supply chains with more complex networks, increasing the risk of disruptions; environmental and social sustainability, which has become a critical issue for stakeholders and requires supply chain managers to adopt sustainable practices; and changing customer demands, which require supply chains to be more agile and flexible to respond to market changes.

Moreover, supply chain risk management has become increasingly important due to the increasing frequency and severity of natural disasters, political instability, and cybersecurity threats. Supply chain managers must identify and mitigate risks to avoid disruptions and minimize the impact on customers and the company's bottom line.

Supply chain collaboration and integration have emerged as essential elements of successful supply chain management. Enhanced collaboration among diverse entities in the supply chain, such as suppliers, manufacturers, distributors, and retailers, can result in improved coordination, heightened efficiency, and cost savings. Supply chain integration involves the alignment of processes and systems across the supply chain, enabling better communication, data sharing, and decision-making.

George and Pillai (2019) found that inventory control policy, information sharing, customer demand, and lead time are key factors that impact supply chain performance. Information sharing was identified as the most significant driver of performance, enabling coordination among supply chain partners and frameworks. Efficient information management is crucial for day-to-day operations at each stage of the supply chain. Kumar (2012) supports this idea, noting that sharing order status can improve customer service quality, reduce payment cycles, and lower labour costs while sharing retail sales data can

mitigate the bullwhip effect. Cloud-based supply chain applications and collaborative platforms also enhance information sharing, as highlighted by Schatteman and Woodhouse (2020).

According to George and Pillai (2019), customer demand pattern is one of the external factors that influence the performance of the supply chain. When customer demand is very unstable and unpredictable, the SC member sends a very fluctuating order pattern for an associated member in a higher stage, which may intensify order variance (which is named as bullwhip effect) through supply chain processes. Forecasting of demand is believed to be one of the key reasons for a bullwhip effect occurrence. It is very important for the members to forecast future demand, but it is also impossible to achieve correctly predicted demand. The uncertainty which flows from it leads to inadequate quantity orders and order variance intensification. Lead time and review period may also have an impact on the performance of supply chains, and they are attributed to replenishment parameters. The period of time starting from receiving an order and delivery of a product is known as lead time.

Among the trends that are discussed by James (2021) which make a certain impact on SC performance is, for example, the rise of e-commerce. E-commerce and omnichannel fulfilment will continue to shape the way organizations identify and establish key priorities, creating challenges with regard to scale and network efficiency while producing new opportunities to gain competitive advantage. E-commerce and omnichannel fulfilment will continue to shape the way organizations identify and establish key priorities, creating challenges with regard to scale and network efficiency while producing new opportunities to gain competitive advantage. Artificial intelligence as well as machine learning are foundational to integrating people, processes and systems in a wide array of operational environments. They are leading to transformation, advancement, and competitive advantage.

As PwC (2016) defines in its report about Industry 4.0 digitization, is about companies shaping themselves into more customer-centric organisations using the tools of e-commerce, digital marketing. They start to pay more attention to social media, and the customer experience. Eventually, each aspect of a business is expected to be transformed by the gradual integration of research and development. All the internal operations such as manufacturing, marketing and sales are expected to be organised into digitalized supply chain ecosystem with new business models, constructed with these advances. The digital supply chain ecosystem should thoroughly utilize a wide range of technologies, such as augmented reality, cloud services, big data reliance, the Internet of Things and 3D printing.

Digitalization has significantly influenced the field of supply management technologies, encompassing areas such as demand planning, asset management, warehouse management, transportation and logistics management, procurement, and order fulfilment (Jenkins, 2020). These technologies contribute to building supply chain resilience, as evidenced by the study conducted by Baumgartner and Malik (2020). For instance, advancements in semiconductor process nodes, following Moore's law, have resulted in a 50 per cent reduction in size every two years, leading to the development of process nodes as small as five nanometers in 2020 (although the rate of reduction has slowed in recent years). Moreover, the computational power utilized for training artificial intelligence models has doubled every 3.4 months since 2012, indicating the rapid advancement of technology in this domain.

Blume global highlights another manifestation of digitalization. For example, the Internet of Things is used to track shipments using GPS navigation. It is also utilized for monitoring the conditions of a storage with advanced management throughout the supply chain. As noted by Eira (2022), numerous businesses are leveraging the full potential of the Internet of Things (IoT) by integrating this technology with key business applications, such as business intelligence software. Through these integrations, companies can utilize the information gathered by IoT devices to empower data-driven decision-making in the

realm of supply chain strategies. This integration of IoT with business applications offers the opportunity to extract valuable analytics and insights, enabling organizations to optimize their supply chain operations based on real-time data and actionable intelligence.

Among the factors that have a contribution to the effectiveness of supply chains on a country level is thought to be the GDP of the specific country. Efficient supply chain management requires careful consideration of logistics costs, which are closely linked to the level of economic development and the composition of a national economy, as highlighted by The Geography of Transport Systems (2022). In advanced economies, where logistics costs can be as low as 8% of delivered costs, various factors contribute to the smooth movement of goods. These factors include well-developed transportation infrastructures, a reliance on the tertiary (services) sector, lower interest rates, healthy competition, advanced information technologies, robust legal systems, and favourable regulations and taxation. Such conducive conditions enable efficient supply chain operations and contribute to a more cost-effective and streamlined movement of goods throughout the supply chain ecosystem.

As economies progress and develop, there is a convergence towards lower logistics costs, which contributes to increased efficiency in the supply chain. Higher levels of economic development are associated with narrower variations in logistics costs among countries, as infrastructure conditions improve and the roles of primary and secondary sectors evolve.

Efficient logistics costs play a pivotal role in optimizing transportation costs, enhancing capacity and reliability, and optimizing transactional and inventory management costs through the adoption of advanced information technologies. By reducing logistics costs, supply chains can operate more efficiently, resulting in improved competitiveness, increased customer satisfaction, and enhanced overall performance.

Another factor that has an anticipated effect on logistics performance of the country is its government's expenditure on transport system and facilities. Governments

play a critical role in creating logistics assets, as discussed by Sheffi (2020), by investing in transportation infrastructure, regulating land use, providing incentives for new asset development, supporting workforce development, and controlling trade and taxation policies. These government expenditures have a positive impact on logistics performance.

Public investment in large-scale shared infrastructure, such as roads, airports, ports, and railroads, is crucial for logistics operations. Governments use various funding sources, such as general funds, fuel taxes, and tolls, to build and maintain these infrastructure assets. For example, the shared use of roads by both truckers and commuters can lead to public support for taxation to fund transportation improvements, which can reduce congestion and benefit logistics operations. In some countries, governments own and operate the national rail network, while in others, they support freight rail despite its private for-profit nature. Rail corridors specifically built for freight, such as the Betuweroute in the Netherlands, demonstrate how government investment in rail infrastructure can improve logistics performance.

Furthermore, governments regulate land use through urban planning, zoning regulations, and building permits, which directly influence the creation of logistics assets such as logistics parks, intermodal terminals, and warehouses. Governments also provide incentives to encourage private investment in logistics development, creating economic opportunities and job growth in specific areas. In addition to physical infrastructure, governments support workforce development through educational institutions and other incentives, which contribute to a skilled labour force for the logistics industry.

The research and works mentioned above majorly concentrate on the influence of digital capabilities on separate aspects of the supply chain performance and specific processes relative to supply chains or logistics rather than on the performance of the whole structure. Also, their approach most commonly involves case studies and qualitative research. Thus, our research will address the gap in the field of studies, that are based on quantitative analysis and incorporate information about the functioning of the

whole supply chain ecosystem and logistics in particular. The findings from the relevant literature should help to identify the key factors that define the level of the supply chain's performance and help to interpret the own research results.

Chapter 3. METHODOLOGY

This chapter describes the model specification methodology and approach to searching and processing data. Reasoning for the chosen methodology will also be discussed and the research hypothesis presented.

In the course of the study, the following hypothesis was proposed:

Hypothesis: the level of digital adoption within a logistics system positively correlates with the efficiency and effectiveness of its operations.

The research aims to give an understanding of whether logistics can be enhanced by implementing digital technologies at a country level. Also, the research aims to clarify the types of technologies that make a major impact on logistics transformation.

Supply chains thoroughly depend on volatile customer demands, which shape their structure and make them complex and sensitive. A high value of a supply chain can only be ensured with an effectively organised transport system. This makes logistics a main critical factor in a supply chain quality. Supply chain improvement flows from effectively working transport, implying a decrease or avoidance of waste of materials and time. Supply chain professionals benefit from products being delivered to the right location on time.

3.1 Approach to searching and processing data

The goal of this study is to estimate the effect of digital adoption rates in the countries across the world and their supply chain performance. As a representative part of a supply chain, the logistics metrics' performance was taken. The Council of Supply Chain Management Professional define logistics as a part of the supply chain system. It is responsible for actualizing and controlling a forward and reverse flow of goods, services and information and its storage in a way that meets customers' requirements.

Logistics, as defined by Michigan State University (2022), encompasses a set of activities that include transportation, warehousing, packaging, and more, which are responsible for moving and positioning inventory, and play a crucial role in synchronizing the supply chain. Thus, results further obtained in the research can be extrapolated on the performance of supply chains as a whole.

Initially, the idea was to find surveys conducted by a number of companies which included information about technologies adopted across time along with information about supply chain features such as warehouse performance metrics or logistics efficiency indicators. Due to a lack of publicly available information, that may be quantified an alternative was introduced. Given that logistics can be taken as a representative part of supply chain due to its undeniable influence on supply chain performance, indicators that reflect its efficiency meet research requirements. For this purpose, data collected by governments and international organisations appeared reliable and convenient source for building models.

The Logistics Performance Index from the World Bank website was taken as a base dataset for the analysis. The overall score in the dataset reflects perceptions of a country's logistics performance based on the efficiency of transport and trade infrastructure, taking into account the effectiveness of customs clearance activities. It also reflects the ability to organise competitively priced international shipments, the visibility of tracking and tracing consignments. The score also takes into account the frequency of goods' arrival to the consignee within the time scheduled.

The index varies from 1 to 5, taking 5 as a score which indicates the highest performance. Data from Logistics Performance Index comes from surveys conducted by academic institutions and international organisations and private companies and individuals engaged in international logistics with the help of the World Bank

As the former dataset doesn't include any digital adoption metrics, there was a need for an additional one, which provides such for the same countries that are listed in the dataset "Logistics Performance Index".

More details about each variable are written in Table 1:

Table 1. Description of Logistics Performance Index data

Name	Symbol	Description
Ability to track and trace consignments	TTC	Represents results from the survey question "Rate the ability to track and trace your consignments when shipping to a given country."
Competence and quality of logistics services	CQ	Results from the survey question "Estimate the overall level of competence and quality of logistics services such as transport operators, customs brokers in a given country.
Ease of arranging competitively priced international shipments	EAS	Results from the survey question "Assess the ease of arranging competitively priced shipments to country."
Efficiency of the clearance process	ECP	Results from the survey question "Rate the efficiency of the clearance process such as speed, simplicity and predictability of formalities by border control agencies in a given country.
Frequency with which shipments reach consignee within scheduled or expected time	FREQ	Results from the survey question "When arranging shipments to the countries listed below, how often do they reach the consignee within the scheduled or expected delivery time?"
Logistics performance index: Overall score	LPI	Reflects perceptions of a country's logistics performance based on the efficiency of the customs clearance activities, quality of trade- and transport-related infrastructure, etc.

Quality of trade- and transport-related infrastructure	QUAT	Results from the survey question "Estimate the quality of trade- and transport related infrastructure such as ports, railroads, roads, IT in a given country."

The digital adoption index (DAI) is a worldwide index which reflects the level of implementation of digital technology from three perspectives: citizens, government, and business. The measures are provided for 180 countries scaling the index from 0 to 1 concentrating more on the "supply side" of digital implementation to make the theoretical linkage clear and to maximise the coverage. The dataset "DAI" was taken as the second part of the combined dataset that should enable the identification of the connectivity of the level of logistics performance within the countries presented in the dataset and with the level of their digitalization.

The overall DAI represents the simple average across three sub-indexes (people DAI, government DAI, business DAI). Each of the three contains technologies that are necessary for the promotion of transformation into the digital era. Those, that are aimed to increase efficiency and accelerate full-scale growth, broaden the possibilities, and improve people's welfare. Those that should also improve the efficiency and accountability of the provision of government services. For most of the countries given in the dataset observations for 2 years are available (2014, 2016). Relative adoption of the digital technologies' measures might be useful for policymaking as it provides the basis for developing the strategy for digital implementation for potential users.

One of the controlled variables that were chosen is a GDP measure of the economic development of the countries listed. The data is taken from the World Bank website. GDP is a widely used economic indicator that measures the total value of goods and services produced within a country's borders during a specific time period. GDP at constant 2015 US dollars adjusts the nominal GDP for inflation, allowing for a

comparison of economic output across different years in real terms, without the influence of changing price levels.

Constant 2015 US dollars are used as a reference year to eliminate the effects of inflation and provide a standardized measure of GDP. This allows for a more accurate assessment of changes in economic activity over time, as it removes the impact of price fluctuations and provides a constant value for comparison.

A controlled variable in the quantitative analysis, which will be included as an independent variable in the model, is obtained from the IMF data website. Specifically, data on expenditure on transport, categorized as a subcategory of expenditure on economic affairs, is included as a variable in the dataset. This variable serves as a controlled factor that can potentially impact the outcome of the analysis and is utilized to assess the relationship between government expenditures on transport and the dependent variable of interest.

Expenditures of the governments in this case relate to different types of transportation administration and services related to the operation, use, construction, and maintenance of various transport systems and facilities. This includes road transport systems such as roads, bridges, tunnels, and parking facilities; water transport systems such as harbours, docks, canals, and terminals; railway transport systems including railroads, terminals, and rolling stock; air transport systems such as airports, runways, and terminals; and pipeline and other transport systems such as funiculars, cable cars, and chairlifts.

To establish the link between digitalization and logistic performance we estimate the following model using the fixed effect method:

$$CQ_{it} = \beta_1 \cdot DAIoverall_{it} + \beta_2 \cdot FREQ_{it} + \beta_3 \cdot EAS_{it} + \beta_4 \cdot \mathrm{ECP}_{it} + \beta_5 \cdot \log(GDP)_{it} + \beta_6 \cdot \log(Exptransport)_{it} + u_{it}$$

All the independent variables are expected to have a positive effect on the competence and quality of logistics services. The intuition of such a prediction is provided below.

The frequency with which shipments reach the consignee within the expected time has an anticipated positive sign. Complete and timely delivery is defined by the effectiveness of the preparation and planning process. It reflects the quality of the pre-production stage. The number of deliveries that have been accomplished just in time and in line with the client's specifications is presented in a calculated measure of success (Kaye, 2011). Timely delivery is a critical measure that reflects the competence of the whole pre-production process. Meeting the client expectations which can be presented by on-time delivery should shape the perception of the quality of the logistics as a whole.

The ease of arranging competitively priced international shipments is one of the aspects that affect the final consumer. A competitive environment stimulates logistics businesses to find competitive advantages and reduce shipping costs in order to guarantee a place in a market. This, in turn, benefits the overall logistics position of the country.

The efficiency of the clearing process mostly includes such characteristics as customs transparency, delivery of timely and relevant information in relation to regulatory changes, number of restrictions and policies for imports and exports, etc. Efficient customs determine the ease of crossing the border and influence the speed of supply chains.

GDP is expected to have a positive impact due to the following reasons. Firstly, increased economic activity, including production, trade, and consumption, as indicated

by a higher GDP, can result in higher demand for logistics services. This includes transportation, warehousing, and distribution, as goods need to be moved and managed across the supply chain to meet the increased demand. Additionally, higher economic activity can lead to more investment in transportation infrastructure, such as roads, ports, airports, railways, and pipelines, which can improve logistics performance by enhancing efficiency, reducing costs, and reducing transit times and congestion.

Secondly, a higher GDP can enable companies to invest in advanced supply chain capabilities, such as information technology, logistics management systems, and supply chain analytics. This can result in improved visibility, coordination, and efficiency in the supply chain, leading to better logistics performance. A higher GDP can also contribute to a more skilled labor force through improved education and training opportunities, which is essential for efficient logistics operations. Skilled labor can handle complex logistics tasks, utilize advanced technologies, and optimize logistics processes, leading to improved logistics performance. Additionally, higher GDP can foster innovation and competitiveness in industries, resulting in the development of new logistics technologies, practices, and business models, which can further drive improvements in logistics performance.

Government expenditure on the transport system of a country can have a positive effect on logistics performance by improving infrastructure, enhancing connectivity, increasing capacity and capabilities, enhancing safety and security, and promoting economic development and competitiveness. These factors can contribute to more efficient, effective, and reliable logistics operations, leading to improved logistics performance for the country.

The main variable of interest (DAI) also has an anticipated positive sign. As was previously discussed in the chapter "Literature Review" digitalization shapes supply management technologies such as asset management, warehouse management, transportation and logistics management, order fulfilment. Artificial intelligence as well as

machine learning and IoT are among those technologies that enable the integration of people, processes and systems in a wide array of operational environments. They are leading to transformation, advancement, and competitive advantage of the businesses operating in logistics. The integrations of digitally enhanced systems potentially provide analytics with the information gathered by IoT devices, giving companies an opportunity to make data-driven decisions on supply chain strategies. That is believed to make the supply chain more agile and more customer oriented.

In addition to control for any time effects, we use a time dummy variable.

Chapter 4. DATA

4.1 Data cleaning

Since the report data in the World Bank and IMF database sites are collected in separate files, it was necessary to collect all the data in one database. Thus, several indicators were taken.

The Logistics Performance Index dataset, Expenditure by functions of Government and Digital Adoption Index are panel types of data. In our study, there are dataset limitations in terms of the available periods (2014, 2016), because these are common years for mentioned datasets. Given the specifics of the three datasets, it might be useful to check models relevant to panel data. Taken datasets will be combined into one on a country basis, and unpaired variables will be eliminated. After this step, both datasets were cleaned from N/A's. The final step is to normalise the variables and create log variables based on the former ones.

4.2 Data description

Our combined dataset has the following features:

- Feature 1: the same objects (countries in our case) are observed repeatedly;
- Feature 2: multiple variables are measured in those same countries;
- Feature 3: the observations take place at two points in time.

Our combined data contains observations about 153 countries across the world and includes data that refers to the 2014- and 2016-year periods. To be representative, the sample observed in research includes different types of countries – from highly to poorly developed, with high and low international trade involvement, different levels of customer demand, different levels of supply chain productivity and different levels of digitalization

and automation adoption. The data descriptive statistics table presented below in Table 2 confirms this statement.

Table 2. Variables descriptive statistics

Variable	Mean	Median	St. dev.	Min.	Max.
DAI overall	0.512	0.523	0.197	0.138	0.870
DAB	0.564	0.582	0.201	0.130	0.974
DAP	0.428	0.418	0.245	0.009	0.897
DAG	0.545	0.551	0.196	0.024	0.992
TTC	2.88	2.76	0.632	1.54	4.37
CQ	2.84	2.72	0.607	1.39	4.27
EAS	2.87	2.79	0.521	1.36	4.23
ECP	2.72	2.59	0.606	1.11	4.20
FREQ	3.26	3.18	0.594	2.02	4.79
LPI	2.89	2.74	0.580	1.59	4.22
QUAT	2.76	2.57	0.680	1.23	4.43
GDP, in bn	481,5	51,59	1799	0,955	1851
Exptransport, in%	1.878	1.781	0.952	0.119	4.682

The standard deviation of the Digital Adoption Index and especially the Digital Adoption Index for people is high, which shows a high dispersion in the values over time and across countries, meaning a presence of listed countries with different levels of digitalization and automation in the sample. However, the standard deviation of the Ease

of arranging competitively priced international shipments index isn't very high, which indicates about the majority of countries being close by the international trade access indicator. Min, max and standard deviation values of Digital Adoption Index (business, people, government) variables also denote a high level of countries' diversity within the sample.

It is worth saying that Digital Adoption Index for people has the lowest mean and max values among all, while the frequency of shipments reaching the consignee within the given time has the highest. This indicates that a substantial part of countries still does not have the full ability to utilize and create digitally advanced services, which is reflected partially by the digital skills level within the workforce. Thus, it can be an important obstacle for countries to support digital innovation in a broad variety of sectors, including logistics. The general demand for digital products and services like mobile cellular penetration, usage of the Internet, and cloud services can reflect on a country's current level of digital readiness.

The descriptive statistics presented in the table for all the variables pertaining to logistics performance indexes reveal that, in each case, the mean is greater than the median. This suggests that the distribution of the data is positively skewed. This, in turn, indicates that the majority of the represented countries exhibit higher values in terms of logistics performance, pulling the mean towards the higher end of the scale.

Furthermore, the descriptive statistics suggest that the distribution of the variables related to logistics performance indexes is relatively homogeneous, with most countries concentrated in the lower or middle stages of logistics development. This finding implies that the logistics performance of the majority of the countries in the sample is comparable, with a limited variation or disparities observed among them.

It is important to note that these observations are based on the descriptive statistics provided in the table and should be interpreted with caution, considering the limitations of descriptive analysis in providing a comprehensive understanding of the underlying

factors influencing logistics performance. Further inferential statistical techniques and analysis of relevant factors are needed to draw more conclusive and robust insights into the logistics performance of the represented countries.

To determine patterns and possible multicollinearity between explanatory variables within a dataset, correlation analysis was conducted (Table 5, Appendix).

First, for both years, correlation matrices were built. Having correlation matrices enabled us to investigate the interdependencies between every two variables in each dataset. We will take a correlation value whose absolute value is greater than 0.8 as such that will mean a high correlation and it will be necessary to review such variables.

The correlation matrix above shows that in most cases the absolute value of correlation exceeds 0.8. The variable Competence and quality of logistics services is the one that correlates the most with the variable Logistics Performance Index (the correlation is 0.98) meaning that one of these variables is redundant for our future model. Given that the variable Competence and quality of logistics services implies the general level of competence and quality of logistics services such as transport operators, customs brokers in a country and a fact, mentioned above we can conclude that one of these can be excluded from the prediction model. Taking into account the very significant correlation of the Logistics Performance Index with other potential variables this one should be dropped. The correlation matrices for 2014 and 2016 are quite related and display approximately the same relationships.

Digital adoption indexes, apart from a high correlation with Digital Adoption Index overall, which basically aggregates all three measures, also show a high correlation value in absolute terms between each other. This can be primarily connected to the fact that the digitalization process cannot affect some entities within the country, such as businesses or the government, without affecting another. Usually, this process occurs simultaneously or with a slight delay for different players. The process of digitalization has led to increased accessibility to information and cost reduction through computerization.

As a result, this has brought about changes in the competitive landscape and the demand for a skilled workforce in the profit-oriented private sector. Technological advancements have not only improved managerial efficiency in the public sector, but have also empowered citizens with more information, connectivity, and demands, leading to the adoption of information and communication technology (ICT) by the public sector to enhance transparency and interaction with government authorities. Consequently, digital transformation in one domain, such as the adoption of technology by society, has catalyzed adoption by other domains, such as business and government.

Correlation between countries' digital indexes and various logistics metrics, shown in the matrix, also exists. We can assume that changes in both occur simultaneously.

By comparison, the correlation between the GDP variable, the Exptransport variable and the rest of the variables from the dataset appears to be relatively low when compared to the correlations observed among the other variables.

Summarizing matrix results, the strongest correlation is observed within digital adoption indexes and within logistics performance metrics. Similar results can be expected in further regression analysis. The correlation matrix introduces a multicollinearity problem.

Multicollinearity most likely will affect the coefficients and p-values. However, the predictions or their precision or the goodness of fit still might not be affected. To detect whether this is a severe obstacle the VIF will be introduced in further analysis.

The fixed effect model was chosen because it is one of the most practical ways to analyze the influence of various factors on logistics services performance. Therefore, having Competence and quality of logistics services as a dependent variable will enable us to analyze the effect on logistics and test the above hypotheses.

Figure 1. Comparing the variable GDP and its log

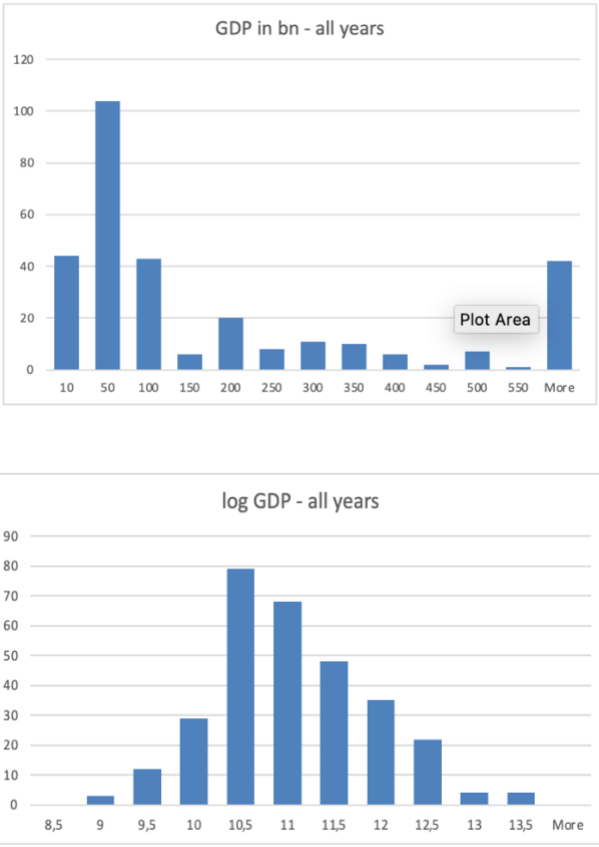
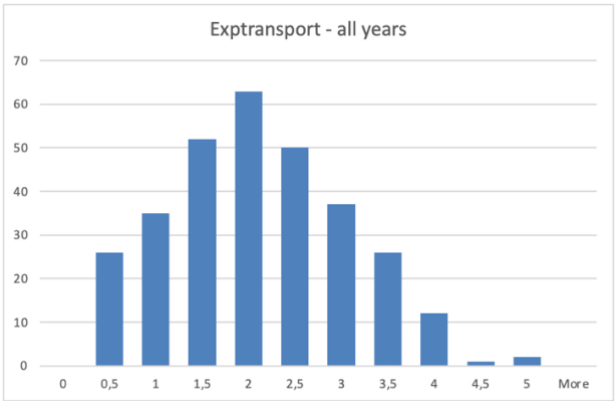
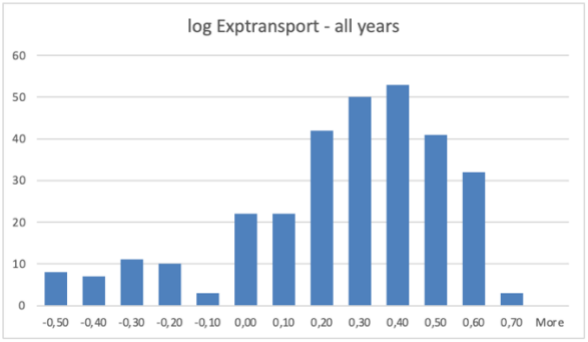


Figure 2. Comparing the variable Exptransport and its log





We will also compare the distribution of key variables and their log forms in the Figures (1,2) to identify best suitable forms. Since the GDP distribution is rather skewed, it was decided to take the logarithm. This is made in order to deal with outliers, smoothen distribution and reduce problems with heteroscedasticity. Applying logarithm to Exptransort appeared to be redundant.

Chapter 5. RESULTS

In the current model examining the Competence and quality of logistics services as the dependent variable, and DAI overall, ECP, EAS, FREQ, log (GDP), and log (Exptransport) as the independent variables, a fixed effect model (FE) was utilized, including a time dummy variable for year 2016. It is worth noting that there exists a moderate level of correlation among some of the independent variables in this model.

Table 3. Coefficients of the FE regression model

Model 1	Estimate	Std. Error	t value	Pr(>|t|)
DAI overall	0.192	0.080	2.401	0.01695*
FREQ	0.249	0.037	6.642	1.473e-10***
EAS	0.201	0.045	4.461	1.159e-05***
ECP	0.447	0.035	12.568	< 2.2e-16***
log(GDP)	0.038	0.006	5.855	1.262e-08***
Exptransport	-0.0098	0.0100	-0. 983	0.326
R^2= 0.933		Adjusted R^2= 0.931		
N= 304				

The findings from the regression analysis revealed that several variables, namely FREQ, EAS, ECP, and log (GDP), exhibited a high level of statistical significance. The p-values associated with these variables were found to be statistically significant, indicating a robust relationship between these variables and the outcome under investigation.

Conversely, the p-value associated with the variable Exptransport did not demonstrate any statistical significance, suggesting that this variable may not have a significant impact on the outcome. Furthermore, the p-value for DAI overall was found to be relatively moderate in terms of statistical significance.

The following conclusions can be made based on the results of this model:

- The frequency of shipments reaching the consignee within the given time is a significant factor. Thus, with the increase of frequency score by 1 unit, the score given to competence and quality of logistics service is expected to increase by 0.24 unit. However, this connection is quite logical because timely service shows the ease of contract enforcement and reduction of export and import time which leads to an increased potential of goods that can be exported, thus increasing logistics competitiveness.
- The ease of arranging competitively priced international shipments is both a statistically and economically significant indicator. The model result shows that with unit increase in this score leads to a 0.2 unit increase in competence and quality of logistics services. This is due to the fact that healthy competition reduces supply chain problems as it decreases abusive market practices. Because in such cases large firms do not have critical market power, thus need to provide good-quality service to remain competitive.
- A positive relationship between the efficiency of the clearance process and the competence and quality of logistics services was also an expected finding. While improving administrative activities at the customs port efficiency is raised which leads to an increase in transportation infrastructure and quality of services. This in turn increases market penetration and reduces transportation costs. Simplification of procedures, documentation allows to mitigate duplication of costs. The result is increased trade volume and growth of economies of scale.
- The findings of our model reveal a statistically significant and economically meaningful relationship between the Digital Adoption index score and the Competence and quality

of logistics services, with a unit increase in the former resulting in a 0.19 unit increase in the latter. This underscores the importance of digital technology adoption in improving the interaction between organizations and businesses, enhancing the exchange of information and materials.

The adoption of digital technologies has brought about significant advancements in logistics operations. The implementation of unified technology platforms has streamlined information flow, automating processes and reducing delays. This has resulted in a quicker and more efficient exchange of information and materials, leading to improved competence and quality of logistics services. Additionally, digital technology adoption has facilitated efficient routing for logistics companies, resulting in cost savings by identifying the most optimal routes, reducing mileage and fuel consumption.

The integration of Artificial Intelligence (AI) technologies in logistics operations has further contributed to process optimization, end-to-end communication facilitation, and cost control. AI-powered systems have enabled logistics companies to analyze large volumes of data, identify patterns and trends, and make data-driven decisions to optimize operations. This has resulted in improved efficiency, reduced costs, and enhanced customer satisfaction.

In summary, our study highlights the significant positive impact of digital technology adoption on the Competence and quality of logistics services. The findings underscore the need for organizations and businesses in the logistics industry to embrace and leverage digital technologies to optimize their operations, improve customer service, and achieve competitive advantages.

- The statistical analysis revealed that GDP is a statistically significant predictor of Competence and quality of logistics services in the model, although it is not economically significant.

Table 4. VIF test results

DAIoverall	log(FREQ)	log(EAS)	log(ECP)	log(GDP)	Exptransport
2.992	6.014	6.727	5.606	2.011	1.079

The VIF method is introduced to point out the problem of the multicollinearity of independent variables when forming a model. The Variance Inflation factor identifies the severity of multicollinearity in regression analysis. This statistical tool measures the increase in the variance of regression coefficients caused by collinearity.

The outcome of the VIF test is presented in Table 4. A high value of VIF points out the high correlation between one variable and the rest. A VIF value above 10 is usually considered to be the one to be highly correlated with other independent variables. As a rule of thumb values that exceed 5 indicate problematic levels of collinearity where model coefficients may not be fully trusted, and their statistical significance is questionable.

Nonetheless, there are also conditions under which high VIF can be safely ignored without having multicollinearity issues. This is the case when control variables present high VIF, but variables of interest do not. Then, variables of interest are not collinear to the control variables and there is not much impact on the regression coefficients.

The findings from our empirical analysis indicate that the majority of variables included in our regression model exhibit VIF values below the commonly accepted threshold of 5. However, it should be noted that an exception was observed in the case of the variable representing the log of ease of arranging competitively priced international shipments, which displayed a higher VIF value. Despite this exception, we contend that this does not impede the reliability of our regression results.

To assure that heteroscedasticity is not an issue for the current model the Breusch-Pagan test was conducted. The null hypothesis, given by the BP test is that model introduces homoscedasticity. The common alpha (level of significance) for this test is 0.05. So, if our tests show alpha <0.05 we can reject the null and state that heteroscedasticity is present. And the opposite is true: when our alpha is higher than 0.05, we fail to reject the null hypothesis and state that heteroscedasticity is not the case for our test. Since our test showed the result of alpha less than 0.01, we conclude that heteroscedasticity is present. Luckily heteroscedasticity does not introduce bias into the coefficient estimates, although making them less precise.

Given that initially our data is considered panel, this allows us to control for variables we can neither observe nor measure such as differences in business practices across organizations. This also allows us to control for variables that have changes over time and do not account for changes across entities (i.e. national regulations and policies). Thus, individual heterogeneity (which we previously had an issue with) is accounted for.

The research hypothesis formulated at the outset of this study has been confirmed by the empirical analysis. Our regression model has revealed a direct impact of digital adoption on logistics performance, which in turn affects the overall efficiency of the supply chain. The observed results not only exhibit statistical significance but also hold economic significance, meeting the predetermined requirements for our investigation.

The findings of this study support the notion that digital adoption plays a crucial role in shaping logistics performance and, consequently, the efficiency of the entire supply chain. The integration of digital technologies in logistics operations has enabled organizations to streamline processes, enhance information exchange, and optimize routing, resulting in improved logistics performance. This, in turn, has a direct impact on the overall efficiency and effectiveness of the supply chain.

The statistically significant results of our analysis provide robust evidence to support the positive relationship between digital adoption and logistics performance. The

economic significance of the findings further underscores the tangible benefits of digital technology adoption in the logistics industry. These results validate the initial hypothesis and provide empirical support for the notion that digital adoption positively impacts logistics performance and supply chain efficiency.

The findings of this study align with prior research in the field, adding to the growing body of literature on the role of digital technologies in logistics and supply chain management. The results provide empirical evidence that supports the theoretical framework and underscores the importance of digital adoption as a key driver of logistics performance and supply chain efficiency. These conclusions contribute to the existing body of knowledge in the field and provide insights for both academia and industry practitioners. In the next chapter, the detailed conclusions and recommendations that stem from the discussed results are presented.

Chapter 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Research conclusions

The global digital transformation has brought many changes to our daily lives and the activities and processes of various economic actors such as businesses, organizations and governments within a number of industries. The supply chain is not an exception.

A number of research has already been conducted in relation to changes in digital implementation and technological development that affect the performance of different components of supply chains, including logistics. And indeed, even though the main advantage of digitalization processes such as increased speed and transparency of processes.

This paper took a closer look at the logistics industry enhancement and the main tools associated with its development. The general market analysis was carried out based on literature research and primary qualitative analysis.

The primary focus of this study was to investigate effects the of Digital Adoption by countries and the influence of this factor on logistic services performance on a country level. In an attempt to do this, we took the Digital Adoption Index data for 2014, 2016, Logistics Performance Index for 2012, 2014, 2016, 2018, countries data on GDP and Expenditures on transport delivered by World Bank and IMF data base. Thus, 153 countries were analyzed in this work.

After collecting the data and transforming the variables, it was decided to use first linear regression for matching periods to determine the influence of factors on the logistics performance. Answering the question of what affects the logistics services performance, majority of the factors that were used in the model turned out to be statistically significant. All of them had a positive effect on the score given to country's logistics performance. That is, with their increase, the competence and quality of logistics

services score also increased. The list of these factors includes the frequency of shipments reaching consignee within the given time, ease of arranging competitively priced international shipments, GDP, efficiency of the clearance process and aggregated Digital Adoption Index.

The second research question concerned the change in the influence of factors on the competence and quality of logistics services. The hypothesis stating that with adoption of digital technologies the supply chain efficiency increases as well was tested and confirmed. Indeed, with increase in Digital Adoption index by 1%, the associated change in competence and quality of logistics services is around 0.026%.

6.2 Research recommendations

All the variables that were included in the Logistic Performance Index dataset have their separate place in supply chain performance. The importance and implementation of those should be discussed to make the most use of them.

For instance, the frequency of shipments reaching the consignee within the given time basically means how timely is delivery. Timeliness means shaping the punctuality of delivery time. Because of market globalization and modernization, the focus of logistics has shifted from supply only to time and space relationships. Studies also show that with ease of enforcing contracts and with time-related to exporting and importing goods increases the competitiveness of companies, which is led by decreased average costs and higher volume exported. Various findings also conclude that countries, enriched by transport system of high quality, telecommunications, and easily accessed financial services tend to have more competitive export prices, and their export stays resilient with time. Transport connectivity and effective border management are known to be the key factors for fast international trade flow. This can potentially benefit developing countries, where they can better integrate with the global value chain. Transparency of logistics processes can improve the efficiency of control agencies because it reduces the time

needed for the inspection of goods and prevents fraud activities such as counterfeit trade and smuggling or frequently appearing undervaluation.

The efficiency and effectiveness of customs clearance are tightly connected with the ability of customs agencies to be fast, simple, and predictable. Reduced transport costs that are associated with simplified procedures, data transfer, mutual recognition of principals and documents lead to mitigated costs duplication. Overall increased port efficiency leads to better market penetration.

While trading activities are synchronised, and customs-related costs are simplified trading volume is also increased resulting in higher economies of scale. By making the documents relating to logistics services unified countries can reach alignment of their processes and collectively streamline the movements of goods across borders. For example, the possession of an ISO certificate by logistics companies can improve their exporting abilities and competitiveness.

The tracking and tracing component of logistics infrastructure has a strong influence on a country's export performance. It becomes a part of good product marketing and enhances customer satisfaction. Firms obtain a better view of hidden customers' needs in global markets and are perceptive to implementing new technologies which may become a source of improved product development.

Transport infrastructure quality is also important for export trade potential. Reliable and easily accessible transport allows quicker distribution of goods, which results in intensified services provided by firms and their increased competitiveness in a global market. Transport costs can be influenced by such factors as containerization level, types of goods, traffic congestion and export infrastructure and logistics. Well-set infrastructure enhances the flow of information, mitigates market imperfections, and allows for better economies of scale. Another result of efficient infrastructure is mitigated customs delays, compatible standards, sufficient flow of information and time schedules that are better

integrated into the whole system. Reduced transport costs contribute to firms' ability to enter new markets.

Common fact about digital adoption benefits for supply chains, supported by the results of our studies raises the question about ways of implementing digital technologies to acquire the most advantages.

Logistics companies benefit from digital adoption, which increases their efficiency. For example, firms acquire cloud-based software that digitizes their supply chains. This results in centralized operations. Cloud-based solutions also ensure the automated flow of information.

Digital technologies also help trading partners build a transparent relationship. There is a trend among shipping companies to adopt joined blockchain solutions. This is a movement towards the promotion of technological development in various aspects of processes.

Tracking shipments is also enhanced by digital technologies implementation. Customers get better access to tracking orders from beginning to end. Customers no longer have a need to contact companies to check the delivery stage. This develops trust among the involved parties.

Digitalized routing systems allow companies to reduce costs due to reduced delays, shortened routes, fewer driving miles. Another tool for logistics performance improvement is predictive/preventive maintenance. Thanks to this technology companies can conduct remote car analysis and facilitate car maintenance. Potential issues like breakage can be mitigated and downtime of cars can be reduced significantly.

Advanced data analytics and artificial intelligence enable logistics to conduct process optimization, control costs, and provide supply chain management. The Internet of Things, 5G technology, machine learning are part of the big technology list, the most frequently utilized by developed companies.

There is a set of functions that digitalization improves in supply chains in the first place. For example, cooperation is being transformed by information exchange between organizations and within organizations. Virtual services enable companies to form strategic alliances. This can be achieved by pooling the warehouse and transportation facilities across a broad geographical operational area and common logistics hub.

The connectivity feature is enabled by vertical integration between customer and supplier and horizontal integration of business partners and third parties along the supply chain involving end-to-end visibility. Machine-to-machine, cloud-based solutions, social media and mobile when combined, can increase productivity, and provide the ability to reduce errors occurrence and unplanned interruptions.

Supply chain integration ability is supported by technologies Software as a Service, Application Programming Interface, and digital service platforms. This allows connecting of logistics chain parties like customers, shippers, and other logistics services providers. Digital platforms collect information about demand from users, shippers, helping to manage the planning process and suggest the most relevant transport modes which are adjusted to warehouse location and end delivery location. Integration for logistics means that computing systems are linked together with software applications and act as a coordinated logistics chain.

Digital adoption also provides autonomous decision-making, working without outside control. Predictive analysis is one of the tools which deliver autonomy for logistics services. Routine activities can be collected from sensors, satellites, mobile devices and after analysed. This is further used in building algorithms that track the shipment stages in real time and accurately prognose the time of arrival, taking into account port congestion, weather conditions, etc.

The findings of this research highlight the relevance of the topic of digitalization and logistics efficiency from multiple perspectives, including business and industry,

government and policy, and academia and research. Based on these findings, the following recommendations can be made:

1. Business and Industry:

    a. Embrace digitalization: Businesses should actively embrace digitalization in logistics to improve the efficiency and effectiveness of supply chain operations. This may involve investments in technologies such as IoT, big data analytics, and automation, as well as process redesign to optimize logistics workflows.

    b. Evaluate digitalization strategies: Businesses should carefully evaluate different digitalization strategies based on their specific supply chain requirements and goals. This may involve conducting a cost-benefit analysis, assessing risks and benefits, and benchmarking against industry best practices to make informed decisions on technology investments and operational processes.

    c. Foster collaboration: Collaboration among supply chain partners is crucial in realizing the full potential of digitalization in logistics. Businesses should establish collaborative relationships with their suppliers, logistics providers, and customers to enable seamless information sharing, real-time visibility, and coordinated decision-making across the supply chain.

2. Government and Policy:

    a. Formulate supportive policies: Governments should formulate supportive policies and regulatory frameworks to promote digitalization in logistics. This may include incentives for technology adoption, investments in transportation infrastructure, and the development of digital skills and capabilities in the workforce.

    b. Foster public-private partnerships: Governments should foster public-private partnerships to drive digitalization initiatives in logistics. Collaboration

between government agencies, industry associations, and private sector stakeholders can accelerate the adoption of digital technologies and promote knowledge sharing and best practices.

c. Monitor and evaluate impact: Governments should regularly monitor and evaluate the impact of policies and investments in digitalization on logistics efficiency. This may involve measuring key performance indicators (KPIs), conducting impact assessments, and gathering feedback from stakeholders to continuously improve policy interventions.

3. Academia and Research:

a. Conduct interdisciplinary research: Academia and research institutions should conduct interdisciplinary research that integrates supply chain management, logistics, and digital transformation to generate valuable insights and theoretical frameworks. This may involve using country-level data on logistics performance index, GDP, government expenditures on transport, and digital adoption index to analyze the relationship between digitalization and logistics efficiency.

b. Collaborate with industry and policymakers: Academia should collaborate with industry practitioners and policymakers to align research efforts with real-world challenges and needs. Collaborative research can contribute to evidence-based policymaking, provide practical solutions, and facilitate technology transfer and adoption in logistics.

c. Disseminate research findings: Researchers should actively disseminate their research findings through academic publications, conferences, and other knowledge-sharing platforms to create awareness, stimulate discussions, and inspire further research on the topic of digitalization and logistics efficiency.

Several directions for future research areas can be identified to better understand the influence of the adoption of digital technologies on logistics and more broadly on supply chains. Firstly, it could be useful to conduct a survey that encompasses both technology adoption observations and observations about the performance of supply chain nodes. This could give a comprehensive list of measures that make the most significant impact on supply chains. The results of such a study would be beneficial for the development of digitalization strategies for various organizations.

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APPENDIX A

Table 5. Correlation matrix

	DAI overall	DAB	DAP	DAG	TTC	CQ	EAS	ECP	FREQ	LPI	QUAT	GDP	Exptransport
DAIoverall	1.00	0.94	0.96	0.85	0.78	0.79	0.77	0.75	0.79	0.81	0.80	0.22	0.15
DAB	0.94	1.00	0.92	0.66	0.73	0.75	0.73	0.73	0.74	0.77	0.76	0.17	0.19
DAP	0.96	0.92	1.00	0.69	0.76	0.77	0.75	0.74	0.76	0.79	0.79	0.20	0.14
DAG	0.85	0.66	0.69	1.00	0.66	0.66	0.64	0.58	0.66	0.67	0.64	0.23	0.08
TTC	0.78	0.73	0.76	0.66	1.00	0.95	0.90	0.89	0.92	0.97	0.93	0.36	0.14
CQ	0.79	0.75	0.77	0.66	0.95	1.00	0.91	0.93	0.91	0.98	0.95	0.35	0.12
EAS	0.77	0.73	0.75	0.64	0.90	0.91	1.00	0.89	0.88	0.95	0.90	0.29	0.19
ECP	0.75	0.73	0.74	0.58	0.89	0.93	0.89	1.00	0.86	0.96	0.94	0.31	0.14
FREQ	0.79	0.74	0.76	0.66	0.92	0.91	0.88	0.86	1.00	0.95	0.89	0.31	0.15
LPI	0.81	0.77	0.79	0.67	0.97	0.98	0.95	0.96	0.95	1.00	0.97	0.35	0.15
QUAT	0.80	0.76	0.79	0.64	0.93	0.95	0.90	0.94	0.89	0.97	1.00	0.38	0.11
GDP	0.22	0.17	0.20	0.23	0.36	0.35	0.29	0.31	0.31	0.35	0.38	1.00	-0.03
Exptransport	0.15	0.19	0.14	0.08	0.14	0.12	0.19	0.14	0.15	0.15	0.11	-0.03	1.00