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REFLECTIONS OF FINANCIAL DIGITALIZATION ON FOREIGN TRADE AND THE ENVIRONMENT: A CASE OF THE EUROPEAN UNION

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ABSTRACT

With the acceleration of digitalization particularly alongside advances in information Technologies the migration of a wide range of activities to digital environments has become inevitable. Traditional shopping habits are increasingly giving way to online platforms where innovative approaches continually emerge. Thanks to the diffusion of digital technologies, consumers gain the ability to quickly compare and select products suited to their needs from a broad set of options. This transformation compels national and international firms to operate under more competitive conditions. Consequently, the implications of digitalization for the economy and trade should be regarded as strategically important. Extraordinary circumstances such as global pandemics further amplify firms' need to leverage digital technologies to reach customers. In parallel with advances in financial technologies, digitalization is driving rapid and profound transformation in the financial sector; this change affects not only modes of service delivery but also the structural dynamics of international trade. Novel business models enabled by financial digitalization stand out as a decisive driving force in the transformation of traditional trade structures. The spread of digital payment systems and mobile banking can increase the speed and efficiency of commercial transactions, thereby influencing export and import performance. At the same time, aligning financial digitalization with environmental sustainability objectives and enabling a transition to lower-carbon financial architectures through digital solutions should be expected.On the other hand, the expansion of e-commerce volumes can exacerbate environmental pollution stemming from energy use and carbon emissions. The infrastructural components of digitalization generate high energy demand; data centers, cloud computing infrastructures, and continuously operating servers consume substantial amounts of electricity. Especially in developing countries, energy-intensive implementations of digitalization can widen the ecological footprint and diminish the visibility of potential environmental benefits. As e-commerce becomes more widespread, increased logistics activity can also raise transport-related carbon emissions.The environmental impacts of financial digitalization exhibit a complex pattern; the direction of these impacts varies depending on the quality of digital infrastructure, the composition of energy sources used, and whether the regulatory framework is oriented toward sustainability.

Keywords: Financial Digitalization, Financial Technologies, Foreign Trade, Environment
JEL Clasifications: F10, G20, O33, Q56

1. INTRODUCTION

It is increasingly argued that, with the acceleration of digital transformation in recent years, financial digitalization has fundamentally reshaped the nature of international trade. This transformation is understood not to be confined to improvements in access and speed of financial transactions; rather, it has reconfigured export and import processes. Through online banking, mobile payment systems, e-commerce, and fintech solutions, the cost components of trade are changing, firms' access to global markets is being facilitated, and cross-border transactions are becoming faster, more transparent, and less costly. These effects are not limited to economic outcomes; they also bring environmental dimensions such as energy consumption, carbon emissions, and the use of renewable energy onto the agenda of current debates.

In the literature, the impact of financial digitalization on trade is typically examined along three main axes: effects on the cost structure of trade, facilitation of market access, and firms' integration into global value chains. In particular, with the strengthening of digital payment infrastructures, the automation of customs procedures, and the expanded use of digital documents, transaction costs in exports and imports are reduced, thereby contributing to an increase in trade volume. These developments are reported to broaden small and medium-sized enterprises' (SMEs) access to international markets and to support financial inclusion. Digital finance solutions capable of overcoming traditional trade constraints—are emphasized as offering significant opportunities for exporters, especially in developing countries.

The primary objective of this study is to examine, within a comprehensive theoretical and empirical framework, the effects of financial digitalization on exports, imports, and the environment in European Union countries. The selection of the European Union (EU) is motivated by the high degree to which digitalization in the region has been institutionalized and steered by policy instruments.

It is posited that the technological innovations offered by financial digitalization are effective in the field of trade finance and enable firms to conduct external trade transactions more rapidly and with lower risk. This situation is considered to mitigate financing and trust-related obstacles encountered in entering new markets, allowing firms to leverage competitive advantages based on product differentiation more effectively. Digital financial tools, by reducing information asymmetry across countries, are argued to contribute to the development of more accurate market forecasts and to the optimization of pricing strategies. With the adoption of digital solutions in logistics and supply chain processes, the movement of goods has become more transparent, traceable, and cost-efficient; this, in turn, accelerates import procedures and enhances economic efficiency.

At the same time, the effects of financial digitalization are not confined to economic outcomes, but bring new discussions in environmental dimensions such as energy consumption, carbon emissions, and the use of renewable energy. In this context, the environmental effects of financial digitalization are evaluated within the framework of the Environmental Kuznets Curve (EKC) hypothesis. The hypothesis posits that environmental pollution may increase in the early stages of economic growth, but that, after a certain income level is reached, a declining trend in pollution may be triggered. The EKC approach underscores that the environment–development relationship follows a nonlinear trajectory and that environmental degradation can evolve in different directions depending not only on economic growth, but also on structural transformation, technology adoption, and policy choices. The environmental impacts of digital technologies and financial digitalization should therefore be assessed within the EKC framework, considering both their positive and negative aspects.

It is further argued that financial digitalization may influence this process through both direct and indirect channels. The proliferation of digital banking, mobile finance applications, and blockchain-based systems facilitates the development of environmentally friendly financial products and enhances resource-use efficiency. Digital financial solutions are said to expedite the issuance processes of green bonds, support carbon abatement, and strengthen the traceability of sustainability-oriented investments. In addition, through environmentally focused mobile applications such as those enabling energy consumption monitoring and carbon footprint calculation digital tools can raise individual awareness and foster transformations in consumer behavior.

2. Conceptual Framework

2.1. Digitalization of the Financial Sector in Türkiye

In alignment with global trends, Türkiye has established a digital transformation roadmap. Within this framework, the rapid implementation of the steps required for digital transformation and the structuring of physical infrastructure and human capital have been prioritized. The financial sector has adopted a customer-centric approach and directed a substantial share of its investments toward digitalization. In the banking sector the principal actor in financial markets core digital tools such as Near Field Communication (NFC), cardless cash withdrawal and deposit, fingerprint authentication, and mobile banking have been developed. The vast majority of banks have deployed digital applications incorporating artificial intelligence (AI), and AI solutions have become a critical instrument in interbank competition. An examination of AI use by banks in Türkiye indicates that the number of customers benefiting from these services is increasing and that the applications are being used effectively (Gümüş et al., 2020). The intensive adoption of AI applications in parallel with the development and diffusion of internet banking is considered a key factor in the decline of branch numbers and in-branch customer density. Heightened competition in banking has made a substantial contribution to the rapid progression of the digital transformation process (Yücel et al., 2023).

Considering the digitalization trajectory of the banking sector in Türkiye, technological advances have given rise to products and services that offer easier and faster access. In line with these developments, the diversification of alternative distribution channels has increased interest in mobile and digital banking and has played a decisive role in the decline in the number of branches and employees (Tang vd., 2024).

Banking is noted as one of the areas where digitalization was adopted early in Türkiye. According to the 2023 report of the Banks Association of Türkiye (TBB), 28 TBB-member banks offer internet banking services, while 22 provide mobile banking. The number of digital banking customers (individual and corporate) in Türkiye is reported to have reached approximately 100 million; 87,362,000 people transact exclusively via mobile banking, whereas 2,114,000 use only internet banking (Schueffel, 2016).

An evaluation of the digital transformation in Türkiye's financial sector shows that services and products aligned with advances in information technologies are being developed. These services and products provide individuals with easier use and faster transaction capabilities; correspondingly, while the numbers of branches and employees have declined, increases have been observed in the use of ATMs, mobile and digital banking, credit cards, and AI applications. In this context, it is stated that the digitalization process in Türkiye's financial sector began early and has continued with sustained momentum (Yücel et al., 2023).

Applications of information technology, organizational structures and characteristics, leadership and employee competencies, and ethical values are identified as determinants of digital transformation in the financial sector. The advancement of digital transformation simultaneously enhances both cooperation and competition among different actors within the financial ecosystem, thereby creating a fertile environment for the rapid emergence of new business models. Greater diversification and digitalization in the sector prevent any single financial institution from exercising unilateral dominance over the market and enable the provision of services more rapidly and at lower cost (Michael et al., 2022).

The financial sector supports new business models that facilitate individuals' access to credit opportunities. Accordingly, it is anticipated that the propensity to access such resources will strengthen as digital technology becomes more widespread. Financial digitalization is evolving

along a customer-centered axis, and digital technologies are reported to have positive effects on customer experience. The primary reasons for this positive effect are summarized as the ability to perform more transactions in less time, the reduction of time costs due to increased transaction speed, and the greater ease of access to resources.

2.2. The Evolution of Digital Technologies and Their Financial Impact

Increasing globalization, together with intensifying competitive conditions, has led—concurrently with technological advances to marked differentiation in firms' service processes. Among the primary drivers of this differentiation are developments in information technologies and the acceleration of digitalization. The long economic waves known as Kondratiev cycles are noted to be associated with inventions and technologies that transform not only production processes but also ways of life (Taşel, 2020).

Following the steam, steel, electricity, and petrochemical revolutions, network-based digitalization has risen to become the driving force of business and private life today. It is stated that the Internet, which began to proliferate in the 1990s, enabled information technology systems to be interconnected rapidly and at low cost. Innovations in information and communication technologies (ICT) are regarded as radical; their characterization as general-purpose technologies has allowed for extensive technological and organizational changes across numerous activities. Inventions such as the telegraph and the Internet are emphasized to have required large-scale infrastructure investments following their emergence and to have influenced the business strategies of all firms beyond the telecommunications and information sectors. Information technology is now considered a general-purpose technology; in this context, it is argued to facilitate corporate investment and coordination, reduce costs, and trigger productivity growth. By enabling firms to offer new products and services, IT is said to generate positive externalities in dimensions of timing, quality, and variety, laying the groundwork for broad diffusion across industries and the formation of a rich product spectrum (Michael et al., 2022).

On the other hand, differences in countries' economic performance and global competitiveness are stated to depend largely on the adoption, accessibility, and level of use of ICT (Mitrović, 2020). ICT is reported to have significant effects on economic development; Fernández-Portillo et al. (2020) highlight ICT's substantial contribution to countries' economic growth (Fernández-Portillo et al., 2020).

In various growth theories, technological change is posited as central to the fundamental source of economic growth. These theories maintain that innovation is the principal driver of growth in the global economy. Moreover, numerous studies investigate the scope of innovation's contribution to competitiveness and to the growth of firms, industries, and national economies. Accordingly, the concepts of technological change and innovation have become critical areas of inquiry for researchers across many dimensions. In most early models, technological progress exemplified by Robert Solow's approach was treated as a time-dependent exogenous process; within this framework, technological progress is taken as exogenous while the impact of capital accumulation on economic growth is analyzed. By contrast, endogenous growth models, spearheaded by Romer (1990), argue that growth is driven by technological change arising from the investment decisions of units pursuing profit maximization, and that growth occurs through such innovation-led mechanisms (Taşel, 2020).

Today, the acceleration of digitalization and the emergence of new technologies have brought multi-dimensional, critically important issues to the fore. New digital technologies and the Internet are said to reveal significant potentials for enhancing economic efficiency; they markedly reduce search, entry, access, and reproduction costs. Nevertheless, these

transformations in cost structures can pose various challenges for new institutional arrangements, particularly in areas such as the valuation and protection of innovation, firms' data use, and consumer privacy (Chen, 2020). Information and communication technologies are noted to influence global trade patterns through transaction costs on both the supply and demand sides; these effects were demonstrated by Abeliansky and Hilbert (2017). As economic processes become increasingly digitalized, a dynamic emerges that guides the reorganization of economic activity.

2.3. The Employment Effects of New Technologies

Alongside new technologies, advances in the Internet of Things and artificial intelligence are transforming individuals' ways of living and working, while also reshaping how countries and firms interact on a global scale. It is anticipated that companies aiming for success under intensifying global competition will leverage smart robots in production and distribution processes, and deploy AI-based systems in R&D, marketing, and management; they will also activate robust digital infrastructures that enable information exchange with the external environment (Kükmen, 2021).

Digital transformation is acknowledged to simultaneously affect and reshape social and cultural structures, the economic order, modes of production, occupational definitions, and labor markets. Digital technologies create value for firms and employees by strengthening the organizational, analytical, and managerial dimensions of production; in parallel, they diminish the importance of certain tasks. Although they disrupt established workplace practices, they are also reported to markedly improve knowledge management and rule-based processes (Yankın, 2018).

Concerns persist that robots may replace human labor in the future and that unemployment may rise worries that were similarly observed during past industrial revolutions. It is argued that technological advances generate new job areas and competency requirements, and therefore persistent long-term increases in unemployment are not expected. With technology, job models centered on decision-making, guidance, management, and continuous implementation–improvement have emerged; industrial innovations are highlighted as creating new occupations and employment opportunities. As the use of industrial robots in production grows, the demand for specialized personnel to perform robot maintenance and address software issues is expected to increase (Durmaz, 2019).

In the banking sector, new occupations and positions are expected to emerge, such as mixed-reality experience designer, algorithm technician, interactive interface designer, universal service consultant, digital process engineer, and partnership gateway provider (Kükmen, 2021).

The impact of Industry 4.0 on labor markets is assessed as driving the digitalization of many job areas and shifting employment from a structure dominated by unskilled or blue-collar roles toward a qualified workforce possessing advanced technology-use skills. Consequently, it is argued that the current education system must be transformed to meet the anticipated rise in demand for skilled labor. Given Türkiye's labor force structure, it is emphasized that the country should not miss the opportunity to capitalize on the prospects offered by the new industrial revolution to strengthen its position in the global economy (Genç, 2018).

2.4. The Effects of Digitalization in the Business World

It is argued that the impacts of the development of digital technologies on working life can be observed in three stages. In the first stage, ICT positively affects firms' routine activities; in this context, Adetayo et al. (1999) point to "processes within organizations that collect, receive, process, store, and disseminate information together to facilitate, plan, control, coordinate, and

make decisions." The second stage underscores the transformations that the World Wide Web (www) has generated in business, noting that the www offers innovative business models that, through internal and external communication channels with all stakeholders, lead to profound changes. In the third stage, driven by the Internet of Things, robotic systems, big data, and three-dimensional manufacturing, data storage and processing capacity has increased extraordinarily; big data and business analytics have become fundamental components that firms must adopt across all operations to enable more accurate management and strategic decision-making. It is noted that across many fields of activity—including traditional industries new digital technologies such as data analytics, digital communication, connected objects, intelligent systems, and user experience are being put into practice (Göker, 2023).

Thanks to digitalization, firms can develop new ideas, reach wider audiences, use advanced tools to organize and manage their operations, and most importantly offer higher-quality products and services aimed at increasing customer satisfaction and quality of life. Findings from research in ICT affect organizational structures, employees, systems used, working methods, products, and work environments; in line with these developments, different operating models have emerged. During the process of change, alongside traditional work arrangements, new forms of employment such as project-based, part-time flexible, home-based, and remote work have proliferated; the technological progression of digitalization has transformed the form and structure of production, replacing Fordist production patterns with flexible production systems and adding flexible or non-standard workflows. Through ICT-enabled applications, employees have gained more flexible working environments; digital working opportunities have expanded the possibility of working from home, contributing to employees being calmer and more motivated throughout the day; with the elimination of commute-related fatigue and the need to wake up early, working competence can be maintained effectively and efficiently (Michael et al., 2022).

Today, thanks to information technologies, tasks previously considered difficult even for highly intelligent individuals have become feasible; this process has generated multi-dimensional effects in society, the economy, working life, and everyday living, with both positive and negative outcomes. There are strong views that production conducted with Industry 4.0 technologies will yield groundbreaking innovations; at the same time, pronounced contradictions regarding the position of workers in production processes are on the agenda, with potential adverse developments in unemployment and employment being debated. While reaching a definitive judgment is challenging, it is noted that the concerns observed in previous industrial revolutions were gradually replaced by the emergence of new job channels enabled by technological developments and the transformation of worker skills; accordingly, expectations of a persistent long-term increase in unemployment are considered weak (Taş, 2018).

2.5. The Economic Effects of Digitalization

Digitalization is reported to affect the economy at multiple layers. On the production side, digital transformation brings automation of business operations, reductions in transaction costs, and associated gains in operational efficiency. Similarly, digital transformation creates new job opportunities that influence employment and entrepreneurship; in the realm of public services, it enhances the delivery of health and education services while facilitating interaction with public authorities. Digital transformation is also considered to have effects that ease social relations and communication, potentially yielding transformative outcomes for human interactions and individual behavioral patterns. Nevertheless, it is emphasized that digital transformation may also generate potential adverse consequences, such as displacement of the existing workforce, firm closures, cybercrime, and social exclusion (Katz, 2017).

The macroeconomic effects of digitalization are described as multi-dimensional. These effects are expected to manifest largely in macroeconomic domains such as GDP, consumption, investment, foreign trade, employment, and inflation. As shown in Figure 8, the impacts of digitalization on the macro economy are said to materialize through three channels: the labor market, the production function, and three-dimensional (3D) technology. Accordingly, under the relevant heading, the macroeconomic effects of digitalization will be examined comprehensively (Gözüküçük, 2020).

2.6. The Effects of Digital Technologies on Foreign Trade

It is stated that, in line with developments in digital technologies, the existing impact of globalization has increased markedly within the economic order of the twenty-first century. In particular, as ICT usage has become widespread and users' access to Internet technologies has eased, the contemporary understanding of foreign trade is undergoing transformation. Internet technologies are said to erode borders de facto between countries, enabling commercial transactions even in the most remote markets worldwide; in other words, ICT usage facilitates the cross-border flow of ideas, knowledge, expertise, and innovations, thereby contributing significantly to the globalization of the world economy (Mahadevan, 2000).

In the economics literature, the importance of communication costs for international trade has long been recognized; however, since the last quarter of the twentieth century, the increase in world trade has been explained by technological advances in telecommunications and the resultant decline in communication costs (Fink et al., 2005). Innovations in ICT have substituted tools such as telephone, e-mail, and virtual conferencing for face-to-face communication among business partners, rendering physical distance less salient; this transformation is described as the "death of distance" (Ozcan, 2018).

Technological development is highlighted as the principal determinant underlying countries' attainment of competitive advantage, and technological progress is enabled by innovations arising from R&D activities. Advancements in ICT are said to generate profound changes in the production function, on the one hand shaping countries' competitiveness in international markets and, on the other, elevating the prominence of a qualified workforce capable of effectively employing advanced technologies.

Within digital technologies, three-dimensional (3D) printing is expected to significantly affect international trade. This method defined as additive manufacturing or production with 3D printers contrasts with subtractive approaches such as conventional machining and refers to combining materials, typically in successive layers, to create objects from three-dimensional model data (Tezel et al., 2018). Existing production processes often rely on subtractive operations such as milling, grinding, and filing, during which material losses can occur; with the deployment of 3D printing systems, it is anticipated that material waste will decline, production efficiency will rise, and product prices may fall (Gözüküçük, 2020).

Historically, the development and adoption of new technologies for industrial production have markedly reduced production costs; in this context, the proliferation of 3D printers is expected to make mass production more attractive in the future. Should this transformation materialize, world trade is projected to be shaped along five axes: the convergence of regional production and consumption; the shortening of global value chains; a decline in international trade in final and intermediate goods; an increase in raw material trade; and a rise in foreign direct investment.

The increasing use of 3D printers in production implies the substitution of capital and technology for labor, potentially eroding the international competitiveness of countries with

advantages in low-cost labor. For highly industrialized countries, the appeal of offshoring parts of production to low-wage economies is diminishing; conversely, a growing share of production is expected to be carried out in industrialized countries. Producing in the consumer's geography reduces transportation costs and renders domestic production strategic; these developments lead to the execution of all stages of consumer-goods production in locations where consumers reside. Put differently, the concentration of production within national borders in industrialized countries fosters a stronger trend toward regionalization at a global scale; regionalization in production reduces the importance of imported inputs, and as parts sourced from foreign suppliers begin to be produced locally via 3D printers, global value chains in the digital economy are expected to shorten. Manufacturing products close to points of consumption reduces international trade in final and intermediate goods, whereas trade in raw materials that enable 3D printing is likely to increase. Finally, the decline in foreign trade in final and intermediate goods does not mean that firms will be unable to sell goods to other countries; rather, firms are expected, over time, to produce the goods they export in destination countries using 3D printing methods. This will be possible only by expanding production capacity; therefore, a significant increase in foreign direct investment is anticipated in the coming period.

2.7. The Digital Economy and the Digital Trade Approach

In recent years, global trade and digital networks have expanded rapidly, gaining significant momentum. From an economic perspective, the migration of transactions to digital environments has triggered the restructuring of numerous economic activities; together with synchronous communication and enhanced transparency, it lowers search costs, overcomes geographic barriers, and establishes an electronic plane of interaction rather than one defined by physical distance. Digital networks of this nature generate pronounced effects particularly in the context of international trade, enabling buyers and sellers to connect more quickly, reducing search costs, and allowing declines in communication and coordination costs (including logistics-related items). Prior to digitalization, processes largely relied on physical instruments—cash payments, checks, invoices, bills of lading, reports, and face-to-face meetings were widely used. Today, firms leverage digital technologies extensively both in the services they provide and in reaching customers; with the application of Internet-based digital technologies to the production and trade of goods and services, the digital economy approach has become an increasingly critical component of the global economy. The digital economy is generally defined as the set of economic activities within the ICT sector covering telecommunications, the Internet, information technology services, hardware, and software and, in relation to this, the concept of "digital trade" has come to the fore. Although there is no single agreed-upon definition of digital trade, there is growing consensus that it encompasses digitally enabled trade transactions in goods and services—delivered in digital or physical form—involving consumers, firms, and public authorities; in short, all forms of digital trade are enabled by digital technologies, though not all such transactions are necessarily delivered in purely digital formats (Taşel, 2020).

The integration of digital trade applications into business processes increases firms' reach to a broader set of stakeholders and raises the speed with which they respond efficiently to orders; inter-organizational activities including those involving suppliers, distributors, business partners, and customers can be conducted in an integrated manner worldwide through online relationships. Digitalization expands the scale, scope, and velocity of trade, enabling firms to offer new products and services to digitally connected, broader customer bases across the globe. Moreover, small enterprises in particular can exploit new and innovative digital tools to overcome barriers to growth, facilitate payments, establish collaboration, avoid fixed-asset

investments through cloud-based services, and access alternative financing mechanisms (Taşel, 2020).

2.8. The Effects of Financial Digital Transformation on Exports and Imports within the Framework of New Trade Theory

It is noted that New Trade Theory (NTT) emerged in the late 1970s and early 1980s in response to the limitations of the Ricardian Comparative Advantage and Heckscher–Ohlin models in explaining international trade. Traditional approaches essentially ground trade between countries in comparative advantages derived from factor endowments and technological differences; yet, in practice, intense trade flows are observed among countries of different development levels advanced, emerging, and less developed alike. The phenomenon of intra-industry trade, wherein exports and imports occur simultaneously within the same sector, could not be satisfactorily explained by classical theories; hence, NTT was advanced (Krugman, 1979; 1985).

The core assumption of NTT is that firms benefit from economies of scale in production. As output volume increases, unit costs decline, and large-scale production elevates efficiency. Under these conditions, firms will seek to deepen specialization by turning to expanding global markets rather than settling solely for domestic demand. Consequently, countries can specialize in a limited set of products, export those in which economies of scale are maximized, and import differentiated products to enhance domestic variety. This mechanism applies to trade among similar countries as well: each country specializes in particular product groups, gains efficiency, and exchanges these goods through reciprocal trade.

Another assumption of NTT concerns consumer preferences and market structure, placing product differentiation and monopolistic competition at the center. While classical theories assume homogeneous products, NTT posits that consumers prefer differentiated varieties rather than homogeneous goods (Krugman, 1979). Consumers value attributes such as brand and quality and demand richer choice sets; this demand grants producers limited monopoly power over their own variety (Dixit et al., 1977). Because entry is relatively free and firms face competitive pressure, monopolistic competition not pure monopoly prevails; firms aim to access international markets to harness economies of scale; and consumers' taste for variety steers producers toward trade in differentiated products. Thus, exports and imports can occur within the same industry, laying the foundations of intra-industry trade (Helpman et al., 1985; Grossman et al., 1991).

NTT further acknowledges that trade is influenced not only by production or factor costs but also by a broader set of trade costs, including frictional costs. In classical frameworks, transport, tariffs, and non-tariff barriers are listed as primary components, whereas NTT broadens the cost set to encompass information asymmetry, uncertainty, regulatory procedures, and critically financial transaction costs (Helpman and Krugman, 1985). These costs materially affect international trade volumes and firms' decisions to enter foreign markets; there is empirical evidence that information asymmetry reduces trade (Rauch, 1999) and that regulatory delays diminish trade volumes (Djankov et al., 2010). Lower frictional costs can increase the volume and intensity of trade, while high costs can deter it; this perspective enables NTT to convincingly explain the widely observed intra-industry trade among similar countries. Countries specialize in certain product varieties, produce at large scale, lower unit costs, and the trade patterns observed in highly integrated regions such as the EU can be understood in this framework.

Digitalization has transformed many traditional sectors; this transformation is acutely felt in financial services, where the shift to online services has become pronounced (Setia et al., 2013).

Financial digitalization through technologies such as mobile payment systems, Internet access, and online shopping signals the evolution of financial activities and access from traditional methods to digital channels; although definitions vary, it can be understood as a new financial sector in which technology is applied to enhance financial processes (Schueffel, 2016). Advances in Internet banking and digital payment systems, together with the growth of e-commerce, have markedly transformed trade in goods and services; and financial digitalization solutions have increased financial inclusion in regions with limited access to traditional banking infrastructure, thereby facilitating import and export transactions (Al Khatib et al., 2023; Gomber et al., 2017). In this light, financial digitalization acts as a primary impulse for countries' integration into global financial systems and the deepening of globalization.

Financial digitalization carries strong potential to reduce the frictional costs highlighted by NTT. High bank fees, long processing times, and exchange-rate volatility constitute major cost elements in traditional cross-border payments, foreign-exchange transfers, and trade finance; the dominance of the U.S. dollar as a global currency can raise frictional costs via reserve currency mismatches and differences in access to finance, thereby influencing global trade flows (Gopinath and Stein, 2018). By contrast, digital payment solutions, blockchain-based platforms, and FinTech applications accelerate transactions, enhance transparency, and reduce costs; as a result, entry barriers to international trade especially for SMEs decline materially, encouraging more firms to engage in exporting and importing (Arner et al., 2015). Lower trade costs strengthen firms' ability to overcome geographic barriers, expand trade volumes, and, in line with NTT, stimulate market entry.

Financial digitalization tools provide firms with easier and more cost-effective access to finance, enabling them to expand production capacity and invest in new technologies; this pushes firms to exploit economies of scale more intensively. Evidence indicates that SMEs' access to finance is facilitated by digital solutions and that investment rises; as output volume grows, unit costs fall, enhancing firms' competitiveness in international markets and broadening their foreign trade potential (Chen and Li, 2023).

By diversifying alternative financing mechanisms, financial digitalization promotes innovation and the development of new products and services, steering firms toward more niche, specialized, and differentiated outputs. According to NTT, product differentiation underpins intra-industry trade; financial digitalization facilitates the global market reach of differentiated products. Online marketplaces and digital distribution channels allow firms to offer products worldwide without extensive physical assets or wide distribution networks; this increases product variety and provides consumers with a broad array of choices. Direct access to international markets via digital platforms reduces reliance on traditional distribution channels and reshapes market structure (Kılıç Kahraman, 2025).

The impact of financial digitalization on foreign trade is explained through technological innovations that lower trade costs, accelerate information flows, and increase transactional transparency; e-commerce firms increasingly anchor their strategies in digital distribution channels (Khera et al., 2021; Mahadevan, 2000). These developments align with NTT's assumptions of economies of scale and product differentiation: digital platforms enable EU firms to reach broader customer bases, benefit from scale economies, and offer specialized products to global markets; improvements in access to finance enhance exporters' operational efficiency. Evidence also shows that effective adoption of digital applications allows SMEs to access broader markets via digital platforms, thereby strengthening their export capabilities and competitiveness, in line with NTT's predictions about leveraging economies of scale (Ali et al., 2018). Beyond merchandise exports, services exports are strongly affected by financial digitalization; the diffusion of the Internet has generated meaningful increases in services

exports, and robust Internet infrastructure has expanded foreign trade volumes in services, creating new opportunities; the information and communication channels that facilitate cross-border services exports have been reinforced in this process (Freund et al., 2002).

There is growing conviction that digital wallets and mobile payment systems lower transaction costs for small-scale exporters and facilitate access to global markets; digital trade platforms enable individual entrepreneurs, micro-enterprises, and small farmers to market their products at reasonable prices and enter global markets at low cost; adopting digital technologies eases participation in international trade and enhances trade capacity particularly for SMEs (Kılıç Kahraman, 2025; Ahmedov, 2020; Fan, 2021). These dynamics are consistent with NTT's predictions regarding export performance: through the channels of economies of scale and product differentiation, more firms are encouraged to engage in international trade; financial digitalization reduces exporters' costs and facilitates access to new markets, enabling scale previously unattainable, widening product variety, and improving export performance (Gomber et al., 2017).

Financial digitalization similarly facilitates and transforms import processes; the growth of cross-border e-commerce has accelerated the digitalization of imports (Li et al., 2020). Digital trade platforms allow importers to acquire the latest foreign products and technologies at lower cost; financial digitalization increases the share of producer services in foreign trade, easing the integration of emerging economies into global trade (Ahmedov, 2020; Francois et al., 2008). These trends provide consumers and firms with access to a wider global product range, reinforcing NTT's central assumptions.

Financial digitalization serves as an effective lever in reducing import costs; with the widespread use of e-commerce, transaction costs in supply-chain processes have been lowered, enhancing foreign trade efficiency. Companies adopting digital finance solutions substitute for conventional intermediation structures, reducing intermediation costs in import–export transactions; EU countries benefit from these cost advantages via the channels posited by NTT—to import a broader range of goods and services at more competitive prices (Kılıç Kahraman, 2025).

Service imports, parallel to goods imports, are strongly affected by financial digitalization; notably, trade volumes in transport and financial services have increased even in emerging economies, a trend linked to structural transformations supported by financial digital technologies (Francois et al., 2007). Through digitalization, EU countries can import services from global suppliers more easily and efficiently, thereby improving domestic economic efficiency.

Supply-chain efficiency is reinforced by financial digitalization: with stronger positive effects of supply-chain finance on SMEs, more transparent and traceable structures are established, improving SME performance (Ali et al., 2018). Financial digitalization tools enhance transparency, security, and efficiency; they improve product tracking, support the fight against counterfeit goods, and accelerate payment processes through smart contracts (Chang et al., 2019). These advancements reduce supply-chain risks for importing firms while raising efficiency, lowering import costs, and establishing more reliable sourcing channels; they support findings that financial digitalization carries strong potential to increase both the volume and diversity of imports.

Viewed through NTT's analytical lens, financial digitalization emerges as a powerful catalyst fundamentally transforming foreign trade dynamics. By reducing transaction costs, enabling firms to harness economies of scale more comprehensively, and expanding product variety and competition, it has the capacity to stimulate both exports and imports. To fully realize this

potential, comprehensive policy sets are required, including the establishment of appropriate regulatory frameworks, the strengthening of digital infrastructure investments, and the effective management of the transformation.

2.9. The Effects of Financial Digital Transformation on the Environment within the Framework of the Environmental Kuznets Curve (EKC) Hypothesis

The Environmental Kuznets Curve (EKC) is defined as a hypothesis describing the theoretical relationship between economic growth and environmental pollution; it takes its name from the resemblance to Simon Kuznets's inverted-U pattern between income inequality and growth. According to the EKC hypothesis, pollution and resource consumption increase during the early stages of growth; once a certain income threshold is surpassed, environmental quality improves and the relationship exhibits an inverted-U form (Malouche et al., 2015). Structural change mechanisms underpin this transition: as economies evolve from agriculture and heavy industry toward services and knowledge-intensive domains, sectors that consume fewer resources and generate less pollution are expected to come to the fore. Growth is also said to raise capacity to invest in clean production technologies, which reduce waste and increase energy efficiency.

Empirical tests of the EKC hypothesis yield heterogeneous findings. Grossman and Krueger (1995) report differentiated EKC patterns across country groups, while Stern (2004) argues that structural and policy factors play a decisive role in the hypothesis's validity. In the Tunisian case, an inverted-U relationship between pollution and growth is observed (Malouche et al., 2015); however, evidence from the same periods also indicates that growth can harm the environment. These differences can be explained by countries' economic structures, environmental policies, and levels of technological advancement; the conclusion is that the EKC does not possess universal validity and must be evaluated under country-specific conditions. The EKC provides a strong analytical framework for understanding the environmental impacts of growth; yet environmental problems cannot be solved by economic development alone, and effective policy interventions are essential (Malouche et al., 2015).

Financial digitalization is defined as the process by which financial services are delivered through digital technologies and their accessibility is broadened. This transformation fundamentally reshapes traditional financial systems and exerts deep effects on economic growth and social development. The speed and ease enabled by financial digitalization expands access to services and enhances financial inclusion; a McKinsey report defines financial digitalization as "financial services delivered via mobile phones, the Internet, or cards" and emphasizes its potential to support inclusive growth in developing economies. Innovative tools such as mobile payments and crowdfunding reach populations without access to banking services, stimulating economic activity; digitalization accelerates information flows and reduces transaction costs, fostering a more transparent and efficient financial environment; it eases access to finance especially for SMEs supports new business models, and encourages entrepreneurship. Through financial digitalization, services become more accessible and cost-effective; more broadly, digitalization is viewed as a transformative force in the global economy and occupies a central position in growth and development strategies (Kılıç Kahraman, 2025).

Financial digitalization affects environmental sustainability indirectly rather than directly through the environmentally conscious design and use of digital applications. In this context, reducing the carbon footprint of digital financial applications, strengthening integration with green technologies, and promoting sustainable data infrastructures can support the EKC's transition from pollution to decline. As access to financial products and services expands, SMEs and individuals find it easier to allocate financing to environmentally friendly investments; financial digitalization can stimulate green technological innovation, thereby improving

energy–environment performance. Evidence reflecting positive effects on environmental quality and increased financing directed to green projects is reported; platforms such as Alipay's "Ant Forest" are presented as examples that encourage individual users to reduce their carbon footprints and spread pro-environmental behaviors. In some cases, mobile money and FinTech solutions can enhance environmental benefits more prominently than income gains (Gomber et al., 2017).

Second, financial digitalization delivers indirect environmental benefits by increasing operational efficiency and reducing overall resource consumption. Digital financial services reduce paper-based transactions and the need for physical branches, enabling the financial sector to shrink its own environmental footprint; electronic payments and digital document management lower energy and material use. In this regard, financial digitalization has meaningful effects on natural resource consumption, and FinTech can play a role in reducing resource use (Xiaobin et al., 2024). Nevertheless, financial digitalization can also entail adverse environmental outcomes: although e-commerce offers integrations that can enable sustainability, it carries the potential to harm sustainability through carbon emissions, packaging waste, and the environmental impacts of logistics (Oláh et al., 2019). A balance must be struck between financial digitalization and environmental effects; as trade volumes expand, carbon footprints can rise.

Third, digital platforms support environmental governance by reducing information asymmetry and increasing transparency. More transparent data on environmental, social, and governance (ESG) performance can be provided to investors; with greater transparency in international trade, resource tracking becomes feasible, and smart contracts can automate compliance, strengthening adherence to environmental regulations (Gomber et al., 2017). It has been found that financial digitalization, together with environmental regulation, can weaken environmental inequality (Li et al., 2022); this dynamic adds a new dimension of transparency and accountability to achieving environmental goals.

Fourth, the interaction mechanisms between foreign trade and the environment can be reshaped by financial digital transformation. The shift of production from advanced to developing countries may lead to a relocation of environmental impacts rather than absolute reductions; the environmental footprint embodied in imported products can weaken the effect of domestic environmental policies (Kılıç Kahraman, 2025). The link between digitalization and foreign trade, particularly in developing countries, can accelerate production and supply chains, indirectly amplifying environmental impacts (Ali, 2018). On the other hand, international trade can reduce the ecological footprint and contribute to environmental sustainability by lowering carbon emissions (Liu et al., 2024; Shah et al., 2024). In economies where exports are combined with digitalization, the adverse effects on ecological balance tend to be lower; however, in countries where digital trade networks intensify, the risk of carbon leakage can increase through the transfer of emissions to digitally connected trade partners, potentially deepening environmental inequalities (Tang et al., 2024). In some economies, financial digitalization together with digital trade supports green technology and renewable energy use, generating positive effects in reducing the ecological footprint (Shah et al., 2024).

Financial digitalization is assessed as contributing to environmental sustainability by enhancing the green innovation capacity of small-scale enterprises. In regions with high pollutant emission intensity, the impact of digital finance on green innovation is stronger; financial digitalization supports environmental innovation by alleviating financing constraints, improving industrial structure, and stimulating production (Feng et al., 2022; Feng et al., 2022). The direct effect of information and communication technologies (ICT) on CO2 emissions is found to be negative and significant; financial digitalization can improve environmental quality (Khan, 2022). In this

framework, supporting investments in renewable energy is regarded as a critical mechanism that accelerates the EKC's transition to the pollution-reduction phase. The interaction between ICT and renewable energy use exhibits a statistically significant and positive relationship in reducing carbon emissions (Kılıç Kahraman, 2025). While green-oriented technological innovation is thought to play a mediating role in the link between digital financial development and the ecological footprint (Li et al., 2022), digitalization emerges as an important element in pollution abatement and carries substantial potential to facilitate the transition to a low-carbon economy; technological innovation holds the power to enhance environmental quality (Kılıç Kahraman, 2025).

According to the EKC hypothesis, environmental pressures rise at the outset of growth; once income surpasses a certain threshold, pollution declines and the curve turns downward. At this stage, the pollution-reduction process begins; effective policy arrangements such as heightened environmental protection awareness and the adoption of clean technologies play a primary driving role.

Financial digitalization is assessed as accelerating the technical and structural transformation processes envisaged by the EKC. It facilitates access to green technology; alleviates financing constraints to encourage low-carbon production modes; strengthens the green innovation capacities of small-scale enterprises, thereby contributing to environmental sustainability; and exhibits more pronounced effects in regions with high pollutant emission intensity. In this respect, financial digitalization is understood to support environmental innovation through channels that reduce financing constraints, improve industrial composition, and stimulate production (Feng et al., 2022).

Financial digitalization offers strong potential for achieving environmental sustainability goals; however, careful policy design and implementation are required to fully realize this potential. Financial digitalization alone is not sufficient to ensure sustainability; it must be supported with complementary policies and innovations (Karlılar et al., 2023). It is critically important for policymakers, while promoting financial digitalization, to develop regulations that ensure progress aligned with sustainability targets; frameworks such as the Lisbon Strategy endorse the transition to the digital economy, embracing the goal of sustainable growth and the promotion of environmentally friendly technologies. Ensuring environmental equity is strategically important for securing resource-use efficiency in the service of sustainable development (Mitrović, 2020).

Within the EKC framework, an inverted-U relationship is anticipated between growth and environmental pollution. In this direction, the study constructs an econometric hypothesis to evaluate the environmental impacts of financial digitalization within the EKC framework and to empirically test the theoretical structure; it is assumed that financial digitalization will trigger the pollution-reduction stage by facilitating access to environmentally friendly technologies and, after growth surpasses a certain threshold, could reduce environmental pollution.

In conclusion, financial digitalization stands out as a critical instrument capable of accelerating the pollution-reduction phase envisaged by the EKC. Within the view that growth, beyond a certain threshold, reduces pollution, financial digitalization can enable an effective transition by easing access to green finance, supporting investments in renewable energy, and increasing resource-use efficiency; environmental benefits reach their full potential when integrated with appropriate regulations and inclusive digital finance policies; through this pathway, financial digitalization supports growth, reinforces the positive effects anticipated by the EKC, and serves sustainable development by reducing the environmental footprint.

2.10. The Effects of Financial Digital Transformation on Foreign Trade in EU Countries

Digital financial services are assessed as having become a fundamental instrument that facilitates export processes. This effect appears more pronounced in EU countries with higher levels of digitalization. Through online banking, digital payment infrastructures, e-invoicing systems, and blockchain-based logistics-tracking solutions, financial digitalization expands firms' access to foreign markets, reduces transaction costs, and increases transaction speed (Gomber et al., 2017). Within the EU, initiatives such as the Digital Single Market and e-Customs have rendered cross-border export procedures more integrated and transparent.

It is stated that the impact of financial digitalization on exports is felt more strongly in countries with robust digital infrastructure, such as Germany, the Netherlands, Sweden, and Finland. Owing to high fixed broadband penetration and the widespread use of Internet banking and e-commerce services, these countries adopted digital solutions in foreign trade at an early stage. Since 2011, the observed acceleration in financial digitalization has coincided with export growth across the EU; in the same period, the European Commission pursued a policy timeline that expanded digital public infrastructures, digital identity verification, and electronic signature applications. In this way, digitalization and financial digital transformation have holistically integrated the chain from the preparation of export documents to payment systems, reducing commercial barriers and supporting export performance. This positive effect manifests more strongly in economies that export information and communication technologies, digital services, and high value-added industrial goods; exports conducted via digital platforms facilitate SMEs' integration into foreign markets. In this context, financial digitalization is seen not only as raising efficiency but also as serving as a strategic lever that enhances the EU's competitiveness in global trade (Mitrović, 2020).

The impact of financial digitalization on imports is likewise pronounced; it is reported that digital financial services concentrated in Western Europe play an import-augmenting role in Eastern European countries through regional supply chains and cross-border trade linkages (Cao et al., 2022). This indicates that financial digitalization is not merely a technology effective within national borders; rather, through spatial externalities, it reshapes the EU's economic fabric at a regional scale. The spread of digital payment systems, customs data-sharing platforms, and e-logistics applications enables more integrated, transparent, and low-cost import processes; this, in turn, strengthens asymmetric interdependencies between countries. The Central and Eastern European economies (such as Poland, Hungary, Czechia, and Slovakia) exhibit import dependence on trade partners with high digitalization levels, including Germany, the Netherlands, and France; this dependence is evaluated as reinforcing financial digitalization's spatially guiding role.

The strengthening of digital logistics infrastructures in Germany accelerates and diversifies import processes in production- and assembly-focused countries such as Czechia and Poland; thus, by deepening integration at the supply-chain scale, financial digitalization shapes regional import channels. Compared to final-goods imports driven by domestic demand, imports of intermediate and capital goods are more affected by this digital diffusion effect; in economies that have achieved financial digital transformation, sourcing from abroad is organized more efficiently via digital platforms. Consequently, the import composition of countries with more integrated production structures is transformed; financial digitalization shapes the structure of imports indirectly through regional linkages within the production–trade–finance triangle rather than directly (Kılıç Kahraman, 2025).

2.10.1. The Effects of Financial Digital Transformation on the Environment in EU Countries

The environmental impacts of financial digital transformation are not confined solely to CO2 emission levels; rather, they are shaped through intermediary channels such as the energy production structure, access to renewable resources, industrial composition, and the stringency of environmental policy. The influence of digital finance technologies on carbon emissions is neither unidirectional nor homogeneous; instead, it is multi-layered, complex, and contingent upon local conditions. In EU countries, the effect of renewable energy use on CO2 emissions is determined not only by national energy and production compositions but also by mutual interactions with neighboring countries' environmental performance. This mutual interdependence aligns with the EU's regional environmental policy architecture: collective initiatives such as the EU Emissions Trading System (EU ETS) and the European Green Deal define carbon-reduction targets in an integrated manner among member states and render cross-country environmental externalities unavoidable (European Commission, 2023).

In Scandinavian countries that completed the energy transition early (e.g., Sweden, Denmark), environmental impacts remain limited because financial digitalization activities are supported by renewable sources; by contrast, in Central and Eastern European countries with high coal and natural gas usage (e.g., Poland, Czechia), the additional energy demand generated by digital infrastructures translates directly into carbon emissions. This divergence underscores the tight linkage between the environmental impacts of digital infrastructures and the composition of energy supply—a relationship emphasized by Michael et al. (2022) and Tang et al. (2024). As financial digitalization becomes more widespread, rising data-processing volumes increase the use of energy-intensive technologies such as cloud computing and artificial intelligence systems, thereby elevating data centers' energy consumption; this increase affects not only the country hosting the data centers but also neighboring countries due to the supply structure provided via regional grids. In this context, the environmental outcomes of financial digital transformation should be evaluated simultaneously along the axes of energy mix, cross-border grid integration, and regional policy alignment.

3. CONCLUSION

Financial digitalization is defined as the transformation of traditional processes and services in the financial sector through digital technologies. The scope of this transformation encompasses innovative applications such as mobile banking, digital payment infrastructures, and blockchain-enabled financial solutions. As a result, the accessibility and inclusiveness of financial services increase; transaction costs decline; and the efficiency of financial systems improves markedly. However, the effects of financial digitalization are not confined to the financial system alone; they also play a decisive role in trade and environmental processes. In this context, a comprehensive examination of the effects of digital financial instruments on foreign trade and the environment has become a strategic priority for contemporary policymakers. The main objective of the study is to empirically analyze the role of financial digitalization in the European Union countries with respect to foreign trade (exports and imports) and environmental indicators, and to provide policy-guiding recommendations in line with the findings obtained. Considering that the process of financial digitalization in the European Union is supported at the institutional level, and that studies addressing the effects of this transformation on trade and environmental indicators in a holistic manner remain limited, this research is evaluated as offering a timely and original contribution. With this motivation, the study aims to present a multidimensional assessment by jointly addressing the impacts of financial digitalization on foreign trade and the environment.

It is critically important for policymakers to steer financial technologies toward environmental benefit. The promotion of green FinTech solutions is seen as a concrete step toward enhancing the environmental effectiveness of financial digitalization. Sustainable investment platforms supported by regulation, financial products based on low-carbon technologies, and environmentally oriented digital credit mechanisms can generate dual benefits by both transforming the financial sector and accelerating the transition to a green economy. In EU countries, aligning financial digitalization processes with environmental, social, and governance (ESG) criteria is of great importance; by adopting ESG criteria and expanding green FinTech applications through public–private cooperation, developing digital solutions aimed at reducing carbon emissions, and introducing environmentally focused incentive mechanisms for the FinTech sector, it becomes possible to integrate digitalization with sustainable development goals. In this way, individuals can be nudged toward environmentally friendly choices, while practical guidance is provided to policymakers and investors.

The impact of financial digitalization on exports and imports in European Union countries is emphasized as critically important. On the export front, achieving stronger outcomes requires prioritizing the integration of SMEs into digital finance systems across the EU. The expansion of digital payment infrastructures, the alignment of e-export-oriented support mechanisms with EU funds, and the integration of digital financial literacy into the education system play key roles in the process. Given that imports are more heavily shaped by regional interactions, making digital customs systems, blockchain-based supply-chain solutions, and exchange-rate hedging instruments accessible to firms facilitates more integrated and efficient trade flows within the EU.

On the environmental dimension, the study finds that the direct effects of financial digitalization on CO2 emissions are not statistically significant; however, this result does not imply that financial digitalization is environmentally insignificant. On the contrary, the findings obtained within the Environmental Kuznets Curve (EKC) framework indicate that the relationship is not linear but exhibits an inverted-U form with complex dynamics. For EU countries, strengthening the environmental dimension of financial digitalization has become imperative; the development and diffusion of green FinTech solutions play an important role in transforming environmental impacts. Because digital finance applications that enable the monitoring of carbon emissions, sustainable investment platforms, environmentally friendly digital insurance systems, and investment-guidance frameworks via green bonds directly align with the EU's Green Deal targets, incentivizing EU-based FinTech firms in this direction not only strengthens environmental sustainability but also supports economic integration through digital transformation. Policymakers, in line with the European Digital Finance Strategy, should develop a comprehensive framework that jointly addresses the social and environmental dimensions of digitalization; they should internalize ESG criteria into the design of digital financial systems and establish regional funds to reduce digital infrastructure inequalities across the EU. The implementation of targeted support mechanisms for regions with relatively low levels of digitalization in Eastern and Southern Europe is of critical importance for regional cohesion and integrated sustainability.

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