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More digitalization does not always imply more technology transfer: an analysis within the horizon Europe strategy

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Abstract

Digitalization plays a pivotal role in today's economies, facilitating global collaboration by overcoming geographical barriers and enabling technology exchange. Conventional wisdom holds that digitalization directly impacts technology transfer (TT). However, this relationship is not always straightforward. This research challenges this assumption by arguing that countries with higher levels of digitalization may be less effective in TT activities than countries with intermediate digital performance. Drawing on data from Horizon Europe and the Digital Economy and Society Index, the study conducts a two-stage analysis (first a network analysis, followed by a clustering and ANOVA) covering 411 collaborative projects in 31 countries, involving 2,890 participating organizations. Our findings confirm that countries with intermediate levels of digitalization emerge as leaders within the TT network. Furthermore, the study sheds light on specific digitalization indicators (connectivity, human capital, and the integration of digital technology) that can improve the position of European countries within the network.

Keywords Collaboration · Digitalization · Horizon Europe · Network · Technology transfer

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1 Introduction

Digitalization has emerged as a critical factor for competitiveness in today's economies (Adebanjo et al., 2021; Adomako et al., 2021; Del Giudice et al., 2021; Matthess & Kunkel, 2020; Teruel et al., 2022). Its significance is underscored by its capacity to enhance connectivity, streamline processes, foster innovation, and enable access to resources and capabilities that were previously inaccessible (Adebanjo et al., 2021; Chirumalla, 2021; Del Giudice et al., 2021). By overcoming geographical barriers, digitalization not only facilitates global collaboration but also establishes essential connectivity bridges, enabling the exchange of technological resources (Autio et al., 2021). Consequently, nations embracing digitalization gain a competitive edge, attracting investments, and positioning themselves as agile participants in the global marketplace (Luo, 2021).

TT, an inherent consequence of digitalization (Johnson et al., 2023; Sengupta & Rossi, 2023), enable the creation of solid relationships. In this context, countries make an effort to provide an environment that leverage relationships to enable local entities in acquiring valuable knowledge from external sources (Ritala et al., 2015). TT has the potential to create sustainable competitive advantages and improve competitiveness by driving technological progress and innovation (Ferrer-Serrano et al., 2021; Perkmann et al., 2011). However, effective TT, as an integral element of digitalization, not only signifies the exchange of technological resources but also constitutes a critical catalyst for global collaboration (Lindelöf & Löfsten, 2004). It is well-known that the socio-economic development of countries is significantly influenced by TT (Costantini & Liberati, 2014) as it accelerates digital knowledge through collaboration and networks (Xiao & North, 2017). As a consequence, networks play a crucial role in facilitating collaboration and resource sharing (Battistella et al., 2016; Siegel et al., 2023). Being part of a knowledge network provides access to external technology and opportunities for strategic collaborations (Ferrer-Serrano et al., 2022).

Conventional wisdom suggests that highly digitalized countries will lead the TT process (Matthess & Kunkel, 2020). The underlying reason is that countries with higher levels of digitalization are expected to exhibit more active participation in collaborative networks, leveraging their collective resources and expertise. Moreover, research indicates that digitalization has significant potential as a catalyst for more favorable TT outcomes (Adomako & Nguyen, 2023). This supports the expectation that highly digitalized countries are likely to demonstrate a greater inclination towards collaboration, occupying leading positions in the TT network. However, this relationship is not as straightforward as it might seem. For instance, Ferrer-Serrano et al. (2021) demonstrate that countries with intermediate levels of development (and therefore digitalization), occupy leading positions in collaborative and connectivity networks within the European Union. Thus, the impact of digitalization on TT is a complex issue, and existing literature emphasizes the presence of a gap in understanding this impact in collaboration (He et al., 2020). To address this gap, our goal is to assess the extent to which countries with higher levels of digitalization also transfer more technology, or if, on the contrary, this relationship is not so direct, implying the existence of other factors that may influence this connection.

To delve deeper into this issue, we conducted an analysis by means of a two-stage approach, considering a sample of 411 projects involving 31 countries and 2,890 organizations extracted from Horizon Europe's strategy. Firstly, we analyze the configuration of TT partnerships in relation to digitalization. Secondly, through cluster analysis and ANOVA, we examine differences in participation and position (centrality) on the TT network based on countries' digitalization performance. Conducting a macro-level analysis at the country level, this study identifies digital indicators that significantly differentiate European countries. In contrast to traditional wisdom, our main result suggests that countries with higher levels of digitalization perform less effectively in TT activities compared to countries with intermediate digital performance.

This study is the first to provide a comprehensive characterization of different groups of European countries based on their position in the TT network. By doing so, it sheds light on the digitalization variables that act as enablers for countries' network position. In this manner, our findings offer valuable insights for policymakers and researchers as they challenge conventional wisdom regarding the relationship between digitalization and TT. Furthermore, this study contributes to the understanding of the impact of TT in strategic collaborative networks within the context of digitalization. The visualization of these impacts helps deepen our understanding of technology flows in complex settings, particularly in fostering digitalization projects. Moreover, this study critically evaluates the Horizon Europe initiative, which has not been evaluated to date. The findings and recommendations of this study provide policymakers with actionable suggestions to enhance the effectiveness and success of the initiative, ensuring that it achieves its intended goals in promoting digitalization and TT.

This paper is structured as follows: Sect. 2 presents the theoretical background. The first subsection delves into the existing literature on digitalization and TT collaboration while the subsequent subsection elucidates the connection between TT and collaborative networks and its conceptual implications. Section 3 provides a description of the sample and methods employed and Sect. 4 presents the results, both from the preliminary network analysis (Sect. 4.1) as well as the findings concerning differences in centrality based on the level of digitalization (Sect. 4.2). Finally, Sect. 5 finishes with the main conclusions, implications, limitations, and suggestions for future research.

2 Theoretical background

2.1 Digitalization and technology transfer for competitiveness

Michael Porter, in his seminal work *The Competitive Advantage of Nations* (1990), posits that companies attain competitive advantage through innovative endeavors, yet their ability and impetus to innovate are influenced by the characteristics of their respective nations. These intrinsic attributes coalesce to form the national environment, which in turn serves as the foundation for the dynamics of organizational competition. Building upon this premise, organizations and countries are depicted as interconnected components of a larger system. Consequently, nations furnish organizations with environmental conditions conducive to competitiveness, while organizations contribute to the overall competitiveness of their respective countries.

In contemporary discourse, digitalization, as defined by Horváth and Szabó (2019) as the widespread integration of digital technology across economies, profoundly impacts production, consumption, and the management of organizations and countries. This transformative process offers numerous benefits, including risk reduction and cost optimization (Denicolai et al., 2021), while also expanding the resource and capability pool for organizations (Holmström et al., 2019). In this regard, digitalization can impact resource mobilization strategies, as it can transform how individuals manage assets (i.e. including the search, access and governance of resources) and interact with the environment (Amit & Han, 2017; Inceoglu et al., 2024). For example, Butticè and Vismara (2022) highlighted how digitalization has brought several new players to the entrepreneurial finance arena, changing the game's rules on the crowdfunding strategies of newborn firms. Consequently, digitalization presents opportunities for organizations to achieve competitive advantages. Building on Porter's hypothesis, the positive spillover effects of digitalization on organizations are likely to enhance the overall competitiveness of nations. As organizations leverage digital technologies to improve efficiency, productivity, and innovation, these advancements contribute to the broader economic landscape, ultimately bolstering the competitive standing of their respective countries.

Recent research indicates that digitalization plays a pivotal role in fostering technology exchange by enhancing connectivity in different industries (Steiber et al., 2021), thereby facilitating novel collaborations (Stojčić, 2021; Urbinati et al., 2020). This phenomenon has given rise to the concept of TT, defined as the process of transferring technology or related knowledge across the boundaries of distinct social entities (Battistella et al., 2016; Guerrero & Urbano, 2019; Johnson et al., 2023; Sengupta & Rossi, 2023). While the significance of TT has been extensively debated in recent years (Cunningham & O'Reilly, 2018; Scarrà & Piccaluga, 2022), little attention has been paid to the impact of digitalization on TT within collaborative dynamic frameworks.

Understanding the country-level impact of digitalization on TT in collaborative contexts remains a complex challenge, with a noticeable gap in research within this domain (He et al., 2020). Consequently, there is a growing suggestion that promoting digitalization could enhance ecosystem efficiency through TT, owing to their mutually reinforcing effects (Guerrero & Urbano, 2019; Urbinati et al., 2020).

2.2 Technology transfer and the network theory

The emergence of network theory in the management field has been propelled by the dissolution of geographical boundaries amid globalization and digitalization. The intricate web of interconnections on a global scale has rendered conventional theoretical models, such as the Triple Helix, less pertinent, thereby shifting focus towards network theory (Möller & Halinen, 2017; Tandon et al., 2021).

Building upon the preceding arguments, digitalization serves as a catalyst for collaboration by enhancing connectivity (Bolatan et al., 2022; Ferrer-Serrano et al., 2021), playing a pivotal role in driving social development (Baglieri et al., 2018; Inkpen & Tsang, 2005) and catalyzing economic transformation (Coccia, 2019; Kotabe et al., 2003; Nepelski & Piroli, 2018). Navigating this complexity necessitates collaboration with new actors within the network ecosystem to access strategic partnerships and augment the knowledge base (Dhanaraj & Parkhe, 2006; Swan et al., 1999). Consequently, network members are exposed to diverse sets of resources, including valuable technology, thereby enriching their capabilities.

Thus, TT, as a precursor to innovation performance, manifests through a series of interactions and spillovers within these relational contexts (Farinha et al., 2016). Inkpen and Tsang (2005) delineate two mechanisms operating at this level: (1) networks serving as loci for new knowledge creation, and (2) networks facilitating learning through TT between firms. There is substantial evidence suggesting that actors, whether individuals, organizations, or countries (depending on the level of analysis), significantly enhance their innovative capabilities by leveraging the expertise of others through TT.

Analyzing the configuration of networks enables the modeling of relationships or interactions among a myriad of social entities. This structural analysis facilitates comprehension of the behavior of complex ecosystems, enabling the identification of key actors and evaluation of network performance. Previous literature has explored how the network structure, within which agents are embedded, influences their competitiveness (Ferrer-Serrano et al., 2021; Tsai, 2001; Tsouri & Pagoretti, 2021). It is concluded that the position held by actors, as dictated by the nature of their relationships, interactions, and linkages, is as crucial as their geographical location (Huggins et al., 2012). Consequently, analyses neglecting the interactions among agents within a given network are deemed incomplete and may lead to erroneous conclusions regarding TT.

3 Methods

We conduct an empirical analysis based on two-steps. First, in order to understand and build the TT ecosystem, we perform a network analysis. Second, and once we had the network variables, we explore our research question (are the most digitalized countries the ones who perform better in the TT ecosystem?) by using cluster and ANOVA techniques. Next, we describe the data employed, and in Sect. 4, we described the main methods and results.

3.1 Data collection and sample

The data collection was conducted based on information provided by two different datasets. Firstly, the network construction relied on data from the Horizon Europe strategy.[1] After that, we employ the Digital Economy and Society Index (DESI)[2] for the econometric analysis.

Horizon Europe (2021–2027) has its roots in the Horizon 2020 strategy and stands as the largest research and innovation strategy in terms of funding to date, with a budget increase of nearly 19 percent compared to its predecessor, amounting to 95.5 billion euros. We understand that Horizon Europe, beyond the high volume of funds it manages, is especially appropriate for the understanding of TT for a number of reasons: (i) previous research analyzing resources flows have demonstrated the potential of its predecessor, H2020 (Ferrer-Serrano et al., 2021) in evaluating directional relationships and ecosystem configurations, (ii) it groups a significant number of countries while stimulating interaction and exchange relations among them, and (iii) insofar as most of the countries participating in Horizon Europe belong to the EU, there is a certain homogeneity among them, which makes it possible to isolate the effect of other factors that could interfere in the analysis of the relationships proposed. Horizon Europe provides detailed information on all funded projects that includes general data about the consortium (who coordinates the project and who executes it), and also the amount of funds raised, qualitative information of the thematic project, geographic localization, or the type of organizations involved.

[1] More information: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

[2] More information: https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022

Horizon Europe is structured into three pillars: "Excellent science", which mainly refers to scientific individual talent grants (i.e., Marie Curie funding grants), "Global challenges and European industrial competitiveness", which compels R&D projects that are focused on developing specific innovations, and "Innovative Europe", that represents a policy tool for stimulating market-creating breakthroughs and ecosystems (i.e., the European Innovation Council). Given our research objective, we focused on collaborative projects from the second pillar, specifically within the fourth cluster, "Digital, Industry and Space". According to the European Commission website, this cluster aims to develop innovations based on digital technologies, ensuring sustainable production and consumption while maximizing benefits for society in various social, economic, and territorial contexts within Europe. That is, in the end, its ultimate goal is to enhance European digitalization.

To date, Horizon Europe has financed 413 projects within the fourth cluster,[3] amounting to 2,537,251,636 euros, which represents 21.5% of the total allocated budget. These projects involve the participation of 57 countries, 3,034 organizations, and 5,387 dyads (relationships between two organizational partners). The network analysis presented in the following subsection was performed using this dataset. For our research purposes and considering European digitalization data, we selected only those projects coordinated by countries listed in Appendix 1 (thus excluding external countries) and considered participation from organizations located in those countries. This screening resulted in a final sample of 5,219 dyads, 411 financed projects (totaling 2,125,970,850 euros), and the involvement of 2,890 organizations.[4]

Table 1 provides a country overview of the sample used in this study by country. As indicated, nearly half (44.3%) of the funding from the Horizon Europe strategy is concentrated in three countries: Germany, Spain, and Italy. The remaining 55% of the funding is distributed among 28 countries. The last two columns of the table depict the resources obtained by each country relative to its size (GDP), as well as the number of participations in financed projects relative to its R&D investment. Higher values of these ratios suggest that a country's participation in the strategy exceeds expectations based on its macroeconomic indicators, and vice versa. For instance, Greece and Spain have obtained more resources than expected based on their economic weight. Among smaller and medium-sized economies, Cyprus stands out.

The second dataset utilized is DESI[5] (2021–2022), an index that provides a summary of the most significant indicators of Europe's digital performance and tracks the progress of EU Member States[6] (European Commission, 2020). DESI has been used in previous research to assess the impact of digital technology development across Europe (Moreno-Llamas et al., 2020). DESI comprises four variables. The first one, connectivity, measures the percentage of the population in a country that is connected to the internet. It includes metrics such as mobile broadband, fixed broadband, fast broadband, ultrafast broadband,

[3] More information: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard

[4] Please note that only two projects were entirely excluded from the sample. In both instances, the coordinating country was located outside the European Union (Israel and Serbia). Furthermore, as elaborated in the main text of the manuscript, we excluded specific country participations from outside our sample (Appendix 1). This accounts for the disparities in economic contribution and the number of participations between the total sample and the screened sample employed in this study.

[5] More information: https://digital-strategy.ec.europa.eu/en/policies/desi

[6] DESI tracks the evolution of EU Member States from 2016 to 2022. However, only the years 2021 and 2022 are used since it is the time period matching data from Horizon Europe.

Table 1 Sample distribution. European countries, Horizon Europe contribution and participation to date

Country	EC contribution* (%)	Participations (%)	GDP %	R&D/GDP	EC contribution/GDP(%)	Participations/ R&D investment (%)
Austria	82,20 (3.87)	177 (3.39)	2.14	3.19	1.80	1.06
Belgium	164,77 (7.75)	320 (6.13)	2.65	3.22	2.92	1.90
Bulgaria	11,24 (0.53)	30 (0.57)	0.38	0.77	1.41	0.75
Switzerland	4,45 (0.21)	132 (2.53)	3.57	3.15	0.06	0.80
Cyprus	20,97 (0.99)	47 (0.90)	0.13	0.87	7.78	1.04
Czechia	19,18 (0.90)	56 (1.07)	1.26	2.00	0.72	0.54
Germany	377,62 (17.76)	702 (13.45)	20.37	3.13	0.87	4.30
Denmark	53,77 (2.53)	97 (1.86)	1.78	2.81	1.42	0.66
Estonia	8,96 (0.42)	27 (0.52)	0.17	1.75	2.54	0.30
Greece	164,65 (7.75)	365 (6.99)	0.96	1.45	8.07	4.82
Spain	310,54 (14.61)	717 (13.74)	7.02	1.43	2.08	9.61
Finland	55,85 (2.63)	156 (2.99)	1.33	2.98	1.98	1.00
France	146,59 (6.90)	482 (9.24)	13.20	2.21	0.52	4.18
Croatia	3,32 (0.16)	13 (0.25)	0.31	1.24	0.51	0.20
Hungary	4,80 (0.23)	21 (0.40)	0.81	1.65	0.28	0.24
Ireland	39,90 (1.88)	96 (1.84)	2.25	1.06	0.83	1.74
Iceland	1,23 (0.06)	6 (0.11)	0.11	0.70	0.51	0.16
Italy	253,86 (11.94)	605 (11.59)	9.41	1.49	1.27	7.78
Lithuania	8,66 (0.41)	21 (0.40)	0.30	1.11	1.37	0.36
Luxembourg	26,49 (1.25)	42 (0.80)	0.39	1.02	3.22	0.79
Latvia	2,81 (0.13)	13 (0.25)	0.18	0.69	0.74	0.36
Malta	2,07 (0.10)	5 (0.10)	0.08	0.63	1.23	0.15
Netherlands	168,18 (7.91)	284 (5.44)	4.52	2.25	1.75	2.42
Norway	73,56 (3.46)	107 (2.05)	2.19	2.28	1.58	0.90
Poland	29,74 (1.40)	88 (1.69)	4.52	1.44	0.31	1.17
Portugal	23,01 (1.08)	134 (2.57)	1.13	1.66	0.96	1.55
Romania	10,09 (0.47)	39 (0.57)	1.27	0.47	0.37	1.59
Sweden	14,81 (0.70)	117 (2.24)	2.84	3.36	0.25	0.67
Slovenia	30,75 (1.45)	75 (1.44)	0.28	2.14	5.25	0.67
Slovakia	3,78 (0.18)	17 (0.33)	0.52	0.93	0.34	0.35
United Kingdom	8,14 (0.38)	228 (4.37)	13.94	1.43	0.03	3.06

*Expressed in millions of Euros

and the broadband price index. The second variable, human capital, evaluates the percentage of internet users who possess advanced digital skills. The integration of digital technology is the third variable, that quantifies business digitalization and e-commerce within a country. Finally, the fourth variable, digital public services, measures the extent of e-government and e-health services.

Figure 1 provides a geo-located visual representation of our final sample through a graph depicting the current research ecosystem related to digitalization. The network visualization enables the identification of technology transfer flows among the countries

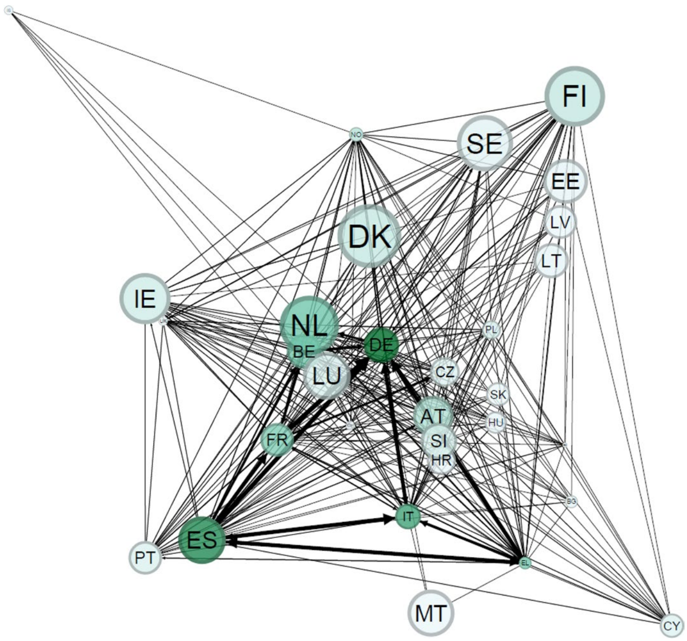


Fig. 1 Network sample representation

participating in the strategy. Moreover, it allows us to incorporate different attributes onto the graph. In this case, the size of the nodes represents the DESI composite index, which measures the technological performance of European countries by considering connectivity, human capital, the integration of digital technology, and digital public services.

Node size is determined by the digitalization composed index. Node colour is associated with the EC contribution of Horizon Europe Cluster 4. The thickness of the links represents the number of projects. The direction is related to the coordination role (origin) and participation (destiny).

4 Results

4.1 Preliminary network analysis

As this study focuses on understanding the influence of digitalization on the structure of TT in Europe, it is essential to conduct a preliminary analysis to provide an overview of the TT ecosystem. This preliminary analysis was carried out using network analysis, a technique that enables the exploration of the ecosystem configured by relationships between entities (Ferrer-Serrano et al., 2021; Zhang & Ji, 2023). In this paper, network analysis allows us to (1) gain a better understanding of how the ecosystem is structured and (2) evaluate the major European innovation strategy to date, thereby deriving policy implications that can serve as guidelines for future directions.

4.1.1 Network analysis

This section explains some theoretical concepts regarding the network characteristics and metrics employed in this paper. Firstly, the focus of this document is solely on directed graphs since we assume that TT flows are directional. In other words, a dyad will always have an origin and a destination, and the flow will not occur in the opposite direction. For our analysis, and following Ferrer-Serrano et al., (2021), we consider the origin of the relationship to be the country that plays the coordination role in the project. This country coordinates and allocates technology resources among the other participating countries, while the destination refers to the remaining countries involved in the project who act as executors. These executor countries adopt and absorb knowledge or technology resources to execute the coordinator's guidelines.

To characterize the network, we employ the concept of *modularity* (Newman, 2006), which is a measure of the network structure or graph that quantifies the strength of division into modules (also known as groups, clusters, or communities). Modularity indicates whether the network's coherence is sensitive to minor changes, such as the removal of a single node resulting in the network being divided into two or more separate parts. Networks with high modularity exhibit dense connections between nodes within modules but sparse connections between nodes in different modules.

$$Q = \frac{1}{2m} \sum_{vw} \left[A_{vw} - \frac{k_v k_w}{2m} \right] \frac{s_v s_w + 1}{2}$$

In addition, various metrics help us understand behaviors within a network. Centrality metrics are essential and widely used for highlighting the significance of an entity's position in the network (Wang et al., 2023). We employ four different metrics to fulfill this purpose.

Degree centrality (indegree/outdegree) (Freeman, 1977) measures the number of links a node has and indicates how well-connected an institution is in terms of direct links. While it accurately represents the level of connectivity of an institution, it does not reflect its position within the network. The theoretical representation of degree centrality is as follows:

$$DC^{v_i} = \frac{d(v_i)}{|V| - 1}$$

where *d(vi)* represents the degree centrality of the node vi in the network. Indegree centrality indicates the number of edges directed into a vertex in a directed graph, while outdegree centrality represents the number of edges directed out of a vertex in a directed graph. The sum of both indegree and outdegree centrality values equals the degree centrality.

Betweenness centrality (Freeman, 1977) quantifies the frequency with which a particular node appears on the shortest path between any two nodes in the network. This metric is employed to measure the significance of an agent in the network and explore the influence that these agents may have on initiating new relationships through potential mediation. Let *np (vj, vk)* denote the number of paths between $vj \in V$ and $vk \in V$. The centrality of the node vi, in terms of connecting vj and vk, is obtained as a ratio. Formally:

$$BC^{v_i} = \sum_{v_j \neq v_k \neq v_i} \frac{\frac{np_{v_i}(v_j, v_k)}{np(v_j, v_k)}}{\frac{1}{2}(|V| - 1)(|V| - 2)}$$

Closeness centrality (Beauchamp, 1965) measures the proximity of a node to other nodes in the network. It can be interpreted as the ability of an agent to connect with other agents. Closeness centrality emphasizes the distance between one actor and others in the network by considering the geodesic distance of each actor from all others. Mathematically, it is represented as follows:

$$CC^{v_i} = \frac{|V| - 1}{\sum_{v_i \neq v_j} sp(v_i, v_i)}$$

where *sp* (v_i, v_i) is the number of connections on the shortest path between the v_i and v_j node.

Eigenvector centrality (Bonacich, 1987) quantifies the importance of a node in the network, taking into account the centrality of its neighbors. It is based on the idea that the centrality of a node depends on how central its neighboring nodes are. Eigenvector centrality provides a more sophisticated measure than degree centrality by considering that not all connections are equally significant. Let *EC(G)* denote the centrality of a vector associated with a network *G*. The key concept is that the centrality of a node is proportional to the sum of the centrality values of its neighbors. Its representation is as follows:

$$\lambda \bullet EC^{v_i}(G) = \sum_{v_j} g_{ij} EC^{v_j}(G)$$

in which g_{ij} takes the value 1 if $(v_i, v_j) \in E$ and 0 otherwise and k is a proportional factor.

4.1.2 Examining TT collaboration network on digitalization

Three distinct graphs have been generated by using the free software Gephi 0.10. In the first scenario (Fig. 2), we present the baseline European ecosystem of TT focusing on digitalization. The second scenario (Fig. 3) highlights collaborative communities and simultaneously represents the digitalization level index of countries. Lastly, the third scenario (Fig. 4) enables us to compare the roles of countries (coordinator vs. participative) within the TT digitalization network. We have chosen these scenarios as they incorporate different graphic representations, thereby providing complementary results that will be statistically tested in the subsequent section.

In Fig. 2, the more central nodes (countries with higher degree centrality) are strategically positioned at the core of the network, while nodes exhibiting lower centrality extend towards the periphery. This spatial arrangement was achieved through the implementation of the *Fruchterman-Reingold* layout, which emulates the dynamic interplay of nodes akin to connected springs. Consequently, the resulting graph reveals three discernible rings delineating the centrality levels of countries within the network. The innermost ring represents countries with the highest centrality, representing the most interconnected entities in the TT network. The second ring consists of intermediate countries in terms of connectivity. Finally, the outermost part of the graph includes countries with less centrality power, indicating their lower level of connectivity within the network.

We can identify a clear pattern here. The most central are countries, notably, Germany, Spain, Italy, France, Belgium, and Greece are positioned within the first tier. It is noteworthy that despite their intermediate levels of digitalization (ranked 12th, 6th, 20th, 14th, 15th, and 25th, respectively[7]), these countries actively strive to attain a strategic and central

[7] The full ranking can be found in Appendix 2.

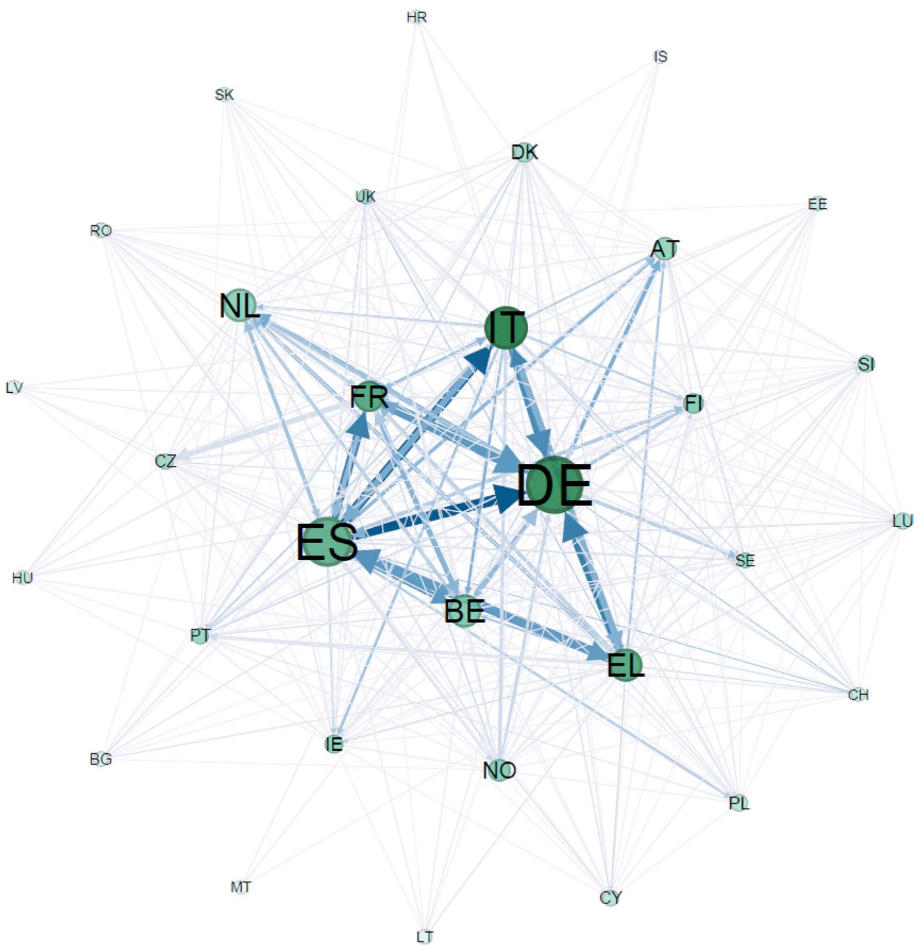


Fig. 2 European network of technology transfer on digitalization (cluster 4 projects)

role within the TT network. Moving outward to the second ring, a cohort of Nordic countries and select Western counterparts with elevated digitalization capabilities are observed. Countries such as the Netherlands (3rd), Denmark (1st), Austria (10th), Norway[8] and Finland (2nd), among others, are members of this level. Finally, the outermost section of the graph encompasses countries characterized by either diminutive size (e.g., Luxembourg, ranked 8th) or diminished innovation capacities (Lithuania 13rd, Romania 27th, Latvia 17th or Slovakia 22nd, among others). A prevailing characteristic of this outer ring is the predominance of members hailing from Eastern European countries.

Graph representation is depicted using *Fruchterman-Reingold* layout. Nodes size is related to the EC contribution for Cluster 4. Colour intensity represents the degree centrality of countries. Links thickness is related to the number of projects in which the dyad

[8] Norway is left out of the DESI analysis.

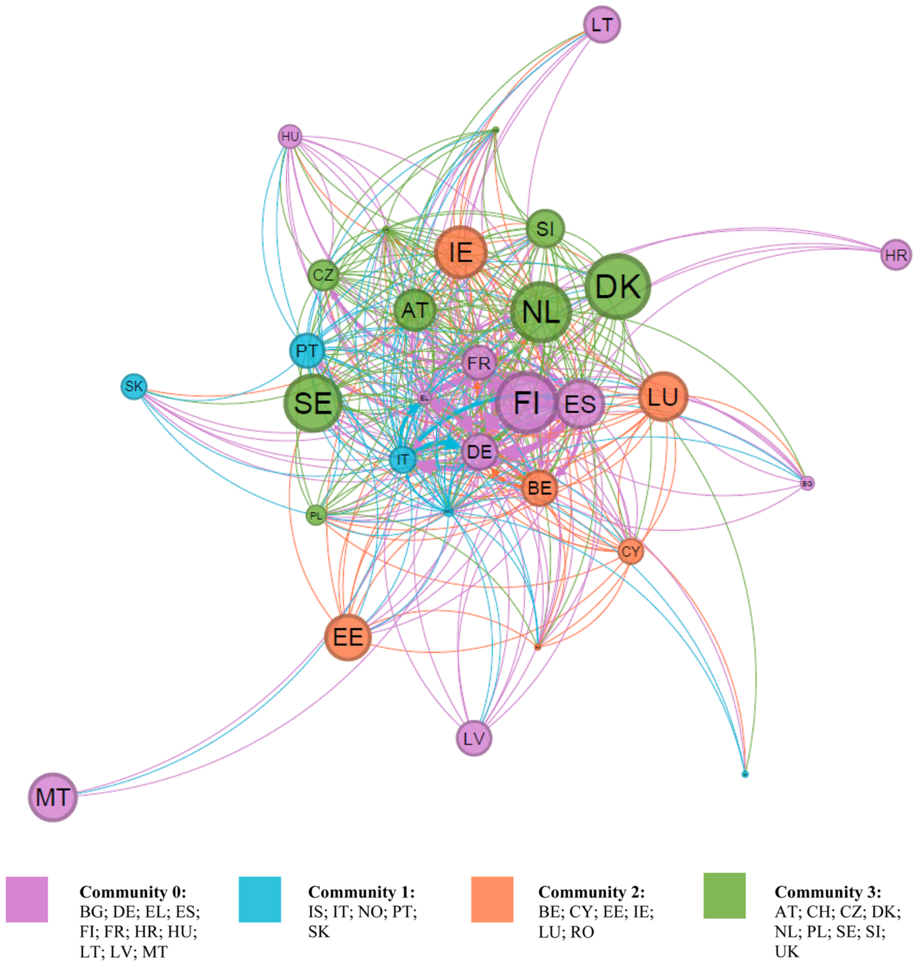


Fig. 3 Technology transfer network communities and the digitalization index. (Graph representation is depicted using Yifan Hu layout. Nodes size is related to the digitalization index provided by DESI. Colour represents the four communities identified based on the modularity of countries. Links thickness is related to the number of projects in which the dyad collaborates together. Links colour intensity is determined by the origin of the dyad collaboration)

collaborates together. Links colour intensity is determined by the number of participations in which the dyad collaborate together.

The second scenario is represented in Fig. 3. This graph is depicted with the *Yifan Hu* layout, a force-directed algorithm employed for visually identifying clusters. This graphical representation substantiates the observations delineated in the preceding graph. Based on the modularity indicator (refer to Appendix 3), we have discerned four distinct communities, each denoted by a unique colour. It is pertinent to emphasize that within a network context, a community signifies a cohesive cluster of nodes characterized by robust

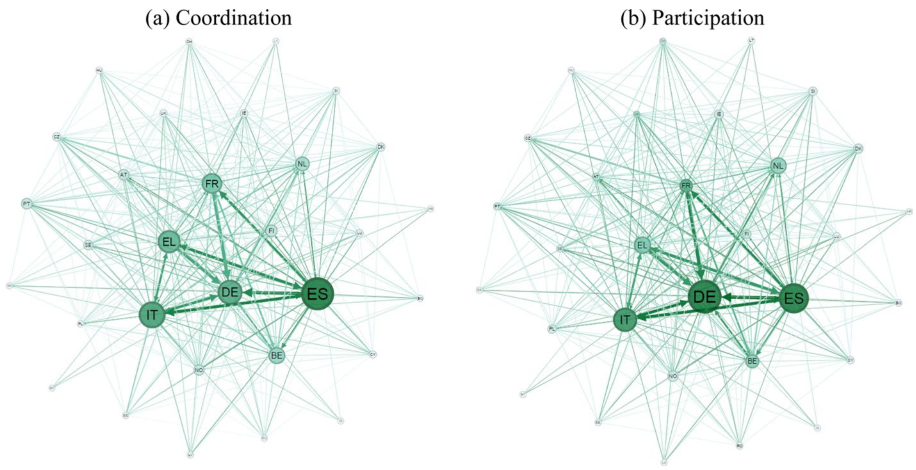


Fig. 4 Coordinator vs participation countries' role on the TT European network. **a** Coordination (Nodes size represents the EC contribution as coordinators. Colour represents the number of projects in which countries coordinate projects (not as participants). Links thickness is proportional to the number of projects in which the dyad collaborates. The mixed colour of the dyad determines links colour intensity). **b** Participation (Nodes size represents the EC contribution as participants. Colour represents the number of projects in which countries participate (not coordinator role). Links thickness is proportional to the number of projects in which the dyad collaborates. The mixed colour of the dyad determines links colour intensity)

internal connections and comparatively weaker connections to external nodes. In addition, the DESI index[9] has been included as an attribute of the network (node size).

The network depicted in Fig. 2 exhibits a medium-to-high density,[10] particularly evident in its inner part, rendering the fragmentation of the network a complex proposition. Corresponding with the conclusions drawn from the antecedent graph, countries at the forefront of digitalization, specifically the Netherlands, Denmark, and Sweden, do not occupy the most central positions within the network. Intriguingly, these countries collectively form a distinct community. In contrast, the community comprising Spain, France, Germany, and Finland comprises countries with the highest centrality within the network. Conversely, countries such as Malta, Lithuania, Hungary, Slovakia, and the Czech Republic emerge as nodes positioned considerably distal from the densely interconnected region of the network. This observation highlights the pronounced spatial heterogeneity in terms of centrality, reinforcing the notion that certain countries, despite their lower rankings in the digitalization spectrum, may exhibit varying degrees of centrality within the overall network structure.

The last scenario (Fig. 4), presents a comparison that explores differences between countries regarding their coordination and participation roles in the TT network on digitalization. It should be reminded that in Horizon Europe projects, there is always a coordinator responsible for leading, allocating resources, and overseeing the project, while other participants primarily execute the project under the coordinator's guidance. The coordination network was built by considering just the cases in which organizations (and therefore

[9] The countries left out of the DESI analysis are Iceland, Norway, Switzerland, United Kingdom.

[10] Density coefficient 0.463 out of 1. This means that half of network is highly dense, while the rest of the network is quite fragile and become fragmented.

Table 2 Results of the centrality metrics

Country	Indegree	Outdegree	Degree centrality	Betweenness centrality	Closeness centrality	Eigenvector centrality
Austria	15	21	36	0.006	0.769	0.742
Belgium	22	21	43	0.030	0.769	1
Bulgaria	8	3	11	0.000	0.517	0.405
Croatia	5	0	5	0	0	0.264
Cyprus	10	12	22	0.002	0.625	0.498
Czechia	14	17	31	0.005	0.698	0.715
Denmark	16	15	31	0.007	0.666	0.780
Estonia	9	9	18	0.001	0.588	0.446
Finland	15	27	42	0.014	0.909	0.755
France	20	27	47	0.048	0.909	0.902
Germany	19	30	49	0.037	1	0.907
Greece	18	29	47	0.039	0.968	0.861
Hungary	10	6	16	0.000	0.556	0.502
Iceland	5	0	5	0	0	0.275
Ireland	17	20	37	0.009	0.75	0.805
Italy	21	29	50	0.054	0.967	0.977
Latvia	7	4	11	0	0.536	0.371
Lithuania	7	0	7	0	0	0.371
Luxembourg	12	15	27	0.002	0.667	0.611
Malta	3	0	3	0	0	0.167
Netherlands	17	22	39	0.013	0.789	0.846
Norway	16	26	42	0.016	0.882	0.795
Poland	17	6	23	0.001	0.556	0.834
Portugal	14	20	34	0.004	0.75	0.723
Romania	16	0	16	0	0	0.768
Slovakia	10	0	10	0	0	0.510
Slovenia	15	15	30	0.003	0.667	0.758
Spain	19	27	46	0.028	0.909	0.903
Sweden	17	16	33	0.007	0.682	0.849
Switzerland	18	0	18	0	0	0.904
United Kingdom	19	14	33	0.007	0.652	0.929

countries where they are located) played the coordination role, and so, their economic funding. On the opposite site, the participation network excludes the data from the coordination network, only remaining the cases where organizations participate as executors. In this sense, the coordination network is depicted on the left side of the figure, while the participation network is shown on the right.

Upon closer examination, several differences can be observed between the two graphs. The most notable disparity lies in Germany's role within the digitalization research ecosystem. Germany appears to take on an executing role, leading projects to a lesser extent. Conversely, Spain exhibits the opposite pattern. While it holds a significant position in both roles, its prominence is more pronounced when it comes to leading research projects. Similar observations can be made for countries like Italy and Greece. In essence, the aforementioned results further reinforce the notion that the "second circle" countries in digitalization are not only actively participating and promoting technological and digital advancements but also taking the lead in shaping the strategy.

Finally, Table 2 presents the results of the centrality metrics and includes European countries that have participated in at least one project. In terms of degree centrality, Italy takes the lead in the ranking, followed by Germany in second place, and Greece and France tied at the same level. Spain occupies the fifth position. This indicates that these countries engage in more frequent interactions with other countries. In terms of TT flows, this implies that they participate in a greater number of collaborations in TT initiatives, establishing a strong presence in the network. Similarly, eigenvector centrality leads to similar conclusions. It considers both the number of collaborations between two countries and the quality of their collaborations. Hence, Italy, Spain, Germany, France, Switzerland, and the United Kingdom stand out due to their high-quality connections with strategic partners in digitalization on the TT network.

Moving on to closeness centrality, these same five countries, along with Finland, demonstrate notable significance. They have the shortest average connection distance compared to other nodes in the network. In other words, if a country aims to transfer technology to another, it is relatively easy to go through one of these countries to reach the destination country more quickly. Lastly, in terms of betweenness centrality, which represents a country's mediation capacity or ability to establish new relationships, Italy, Germany, Greece, France, and Spain emerge again as strategic nodes. They are more likely to initiate new strategic collaboration relationships. The rest of the network should be aware of their capacity and consider them for digitalization research collaborations.

4.2 Digitalization level differences in network position

We conducted a cluster analysis and an ANOVA to investigate the relationship between digitalization and a country's position in the TT network.[11] This section presents descriptive statistics and a correlation matrix (see Table 3). Additionally, we performed a cluster analysis (Ketchen & Shook, 1996; Tokito, 2018) to identify and characterize groups of countries with similar behavior regarding their centrality results in the TT network. Finally, an ANOVA was conducted to compare the variances of group means (Sthle & Wold, 1989; Gil-Lamata et al., 2023) and determine if there are statistically significant differences between them. This analysis aims to identify potential patterns between a country's digitalization and its position in the TT network, and to examine whether the main indicators of the digitalization index (connectivity, human capital, integration of digital technology, and digital public services) influence their network position, addressing the research question posed in this study.

Table 3 presents the key variables' descriptive statistics. The four centrality variables of the TT network were obtained from the Horizon Europe strategy, while the four digitalization variables from DESI correspond to the period 2021–2022. Digital public services exhibit the highest values, followed by connectivity. Human capital also has a notable influence, while the remaining variables have similar levels of influence. The correlation

[11] Both analyses were conducted using Stata 17 software.

Table 3 Descriptive statistics

	Mean	Std. Dev	Min	Max	1	2	3	4	5	6	7	8
1 Degree centrality	27.81	14.76	3	50	1.00							
2 Betweenness centrality	0.01	0.02	0	0.05	0.79***	1.00						
3 Closeness centrality	0.57	0.34	0	1	0.89***	0.65***	1.00					
4 Eigenvector centrality	0.68	0.23	0.17	1	0.86***	0.62***	0.65***	1.00				
5 Connectivity	12.68	2.65	7.78	19.27	0.47**	0.29	0.42**	0.40*	1.00			
6 Human capital	11.93	2.44	7.52	17.85	0.24	−0.04	0.22	0.08	0.38**	1.00		
7 Integration of digital technology	8.84	2.81	3.52	14.77	0.36*	0.14	0.28	0.24	0.42**	0.84***	1.00	
8 Digital public services	16.48	4.08	4.54	22.79	0.10	-0.10	0.23	−0.09	0.30	0.78***	0.70***	1.00

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Cluster's centrality identification and results

		Degree centrality	Betweenness centrality	Closeness centrality	Eigenvector centrality
Cluster 1: leader-centrality (N = 5)	Min	46	0.028	0.91	0.86
	Mean	47.8	0.041	0.95	0.91
	Max	50	0.054	1	0.98
Cluster 2: high-centrality (N = 6)	Min	36	0.006	0.75	0.74
	Mean	39.83	0.015	0.81	0.82
	Max	43	0.030	0.91	1
Cluster 3: medium-centrality (N = 9)	Min	22	0.001	0.56	0.50
	Mean	29.33	0.004	0.66	0.74
	Max	34	0.007	0.75	0.93
Cluster 4: low-centrality (N = 11)	Min	3	0	0	0.17
	Mean	10.91	0.0001	0.20	0.45
	Max	18	0.0005	0.59	0.90
Total	Min	3	0	0	0.17
	Mean	27.81	0.011	0.57	0.68
	Max	50	0.054	1	1
d.f		3	3	3	3

matrix is also presented in Table 3, revealing minimal correlation between the centrality metrics and the digitalization metrics. However, an exception is observed with the digitalization variable of connectivity.

4.2.1 Cluster analysis

To assess the impact of digitalization on a country's position in the TT network, we conducted a cluster analysis to identify countries with similar behavior in terms of centrality (Tokito, 2018). We utilized the four previously identified variables related to centrality metrics (see Table 4). The robustness of the cluster analysis was verified by observing significant variations in the average values of the variables across the clusters.[12] The final cluster solution, based on the original variable values, is presented in Table 4.

The first cluster, that we refer to as "leader-centrality," consists of five countries (Germany, Greece, Spain, France, and Italy). These countries exhibit above-average values in all four centrality metrics, with a particularly high value in betweenness centrality. This indicates their significant relevance in the network and suggests that they likely play a mediating role in establishing new relationships with other countries. The second cluster, labeled "high-centrality," comprises six countries (Austria, Belgium, Finland, Ireland, Netherlands, and Norway). These countries show values above the average in all four centrality metrics, with closeness and degree centrality standing out. As a result, these countries are closely connected to other network countries and possess a high degree of connectivity. The third cluster, "medium-centrality," includes nine countries (Cyprus, Czechia, Denmark, Luxembourg, Poland, Portugal,

[12] Additionally, the results from two stopping rules to determine the cluster number named Calinski-Harabasz pseudo-F index and the Duda-Hart index were applied.

Table 5 One-factor ANOVA (mean and standard deviation)

	Cluster				
	Leader-centrality	High-centrality	Medium-centrality	Low-centrality	F value
Connectivity	15.60 (1.97)	14.43 (2.79)	14.57 (2.27)	12.73 (0.98)	2.59*
Human capital	11.14 (1.57)	14.84 (2.35)	12.30 (2.29)	10.97 (2.26)	3.77**
Integration of digital technology	8.68 (1.40)	12.08 (1.93)	9.96 (2.94)	7.35 (2.78)	4.13**
Digital public services	15.61 (3.98)	19.59 (2.39)	17.63 (2.83)	15.93 (5.62)	1.10

***$p<0.01$, **$p<0.05$, *$p<0.1$

Sweden, Slovenia, and the United Kingdom) that exhibit moderate values across the centrality metrics. Lastly, the fourth cluster, named "low-centrality," encompasses eleven countries (Bulgaria, Switzerland, Estonia, Croatia, Hungary, Iceland, Lithuania, Latvia, Malta, Romania, and Slovakia). These countries demonstrate the lowest importance in the TT network.

The four clusters identified in the centrality analysis and the communities identified by modularity class exhibit similarities. However, there are also some noteworthy differences. For example:

- The *leader-centrality group*, consisting of countries with the most central positions in the network, is primarily located in Community 0 (as identified in Fig. 3). Interestingly, this community also includes countries with low centrality, such as Hungary, Croatia, Latvia, Lithuania, and Bulgaria.
- Countries with intermediate levels of centrality, belonging to the *medium-centrality group,* are predominantly found in Community 3. However, there are exceptions, such as Switzerland (low-centrality) and Austria and the Netherlands (high-centrality), which are also present in this community.
- The *high-centrality group* is distributed across all four modularity communities. Similarly, *the low-centrality group* has countries in all four communities, although the majority are in Community 0.

These differences can be attributed to the fact that clustering solely considers the number of countries related to each other (Watts & Strogatz, 1998). In contrast, modularity takes into account the density of links and assesses whether the network's coherence is sensitive to small changes (Newman, 2006). A visual comparison between the clusters and the communities identified by modularity class can be found in Appendix 3. These results confirm the earlier findings of collaborating communities in the TT network and simultaneously represent the digitalization level index of the nodes. Moreover, countries with top levels of centrality (*leader-centrality* and *high-centrality*) are not necessarily located in the most central positions in the network, while countries with *medium-centrality* achieve higher levels of digitalization. Lastly, the *low-centrality* countries appear as nodes that are highly distant from the densest mesh of the network.

4.2.2 ANOVA

After identifying the four clusters, an analysis was conducted to examine the patterns between a country's digitalization and its position in the TT network. The analysis aimed to understand whether the main indicators of the digitalization index, namely connectivity, human capital, integration of digital technology, and digital public services, influence the country's network position. The within-cluster results presented in Table 5 revealed significant differences in all groups of digitalization variables related to centrality metrics, with notable variations observed in the integration of digital technology. Additionally, connectivity and human capital displayed differences among the four country groups. While no significant differences were identified regarding the provision of digital public services, the groups differed in their levels of connectivity, human capital, and integration of digital technology, which could be considered key variables in determining country centrality within the TT network.

Taking a closer look, it becomes evident that for a country to occupy a position of centrality in the TT network, high connectivity is required. This explains why the *leader*, *high*, and *medium* groups achieved higher levels of connectivity. Similarly, a country's central position in the network necessitates well-qualified human capital and effective integration of digital technology. These factors account for the high levels of these two digitalization indicators across all groups of countries, except for low-centrality countries. Thus, the digitalization variables that act as prerequisites for attaining strategic positions in the TT network are connectivity, human capital, and integration of digital technology.

5 Discussion and conclusions

The literature has assumed that those countries with highest levels of digitalization will also be leaders in TT (Matthess & Kunkel, 2020). However, the empirical evidence that links digitalization and TT suggests that this relationship is not so obvious and that the most digitalized countries not always lead the race towards TT. By means of a two-step approach that combines network with cluster and ANOVA analyses, we confirm that countries with intermediate levels of digitalization perform more effectively in TT than highly digitalized countries.

More precisely, we examine the effectiveness of TT within digitalization projects and analyze the variations between participation and position in the TT network and country digital performance. Our results revealed that three out of the four main digitalization variables (connectivity, human capital, and integration of digital technology) significantly influence the differences in centrality metrics among the four main European country groups. These findings align with previous studies that emphasize digitalization as a catalyst for economic transformation (Coccia, 2019; Kotabe et al., 2003; Nepelski & Piroli, 2018) because digital technologies offer increased resources, capabilities, and learning opportunities (Holmström et al., 2019). In summary, digitalization, as an antecedent of TT, emerges as a powerful tool capable of generating country-level benefits.

One reason that may explain why the most digitally advanced countries occupy more peripheral positions in the network and do not transfer as much technology as expect (Matthess & Kunkel, 2020) is that they may not feel the need to collaborate extensively, as they already possess the necessary support, resources, and capabilities to navigate the digital transition on their own. A complementary explanation can be attributed to cultural factors. According to Hofstede (Hofstede, 1984), countries in southern Europe share cultural characteristics such as higher levels of collectivism and uncertainty avoidance, while countries in the north tend to be more individualist and exhibit lower levels of uncertainty avoidance. In this context, Mediterranean countries, which are leading the TT network, may be seeking technological knowledge and resources to improve their digital performance, mitigating the risks they would face if they were to pursue digital transformation independently. The evident consequence of this apparent disadvantage is the search of new relationships to strengthen their position in the TT network. Given their relatively digital disadvantage, they need to rely on cooperation to achieve their centrality goals. Lastly, low-centrality countries, which are also poorly positioned in the digitalization ranking, depend solely on collaboration with other countries to enhance their digital capabilities.

5.1 Academia and policy implications

This paper holds significant implications for both academia and public authorities. From an academic perspective, this study contributes to the progressive advancement of knowledge regarding TT ecosystems and digitalization. The findings shed light on digitalization's role in shaping countries' position within the collaboration network. Methodologically, our study employs innovative approaches in examining the intricate relationship between digitalization and TT ecosystems. Using complex network analysis techniques (Ferrer-Serrano et al., 2021; Huggins et al., 2012; Inkpen & Tsang, 2005; Tsouri & Pagoretti, 2021) provides a nuanced understanding of the European TT network's configuration at the country level. In this regard, we contribute to the toolbox of research methods available for studying the evolving dynamics of digitalization and TT. Grounded in the network theory, our research addresses existing gaps, further advancing our comprehension of the interplay between digitalization and TT. To sum up, this study contributes with (1) novel insights into the evolving landscape of digitalization and TT ecosystems, enriching the theoretical discourse in these domains; (2) the methodological innovations applied in this research that extend the research methods available for continue investigating the complex interconnections within digitalization and TT; and (3) providing a conceptual scaffold for future research endeavors in this domain.

This study also conveys relevant implications for policymakers that can guide them in developing targeted policies based on the specific needs of different country groups. Our analysis determines that countries interested in improving their position in the TT network should focus on enhancing their digital performance, particularly in terms of connectivity, human capital, and integration of digital technology. By understanding the significance of these factors, policymakers can tailor interventions (through the promotion of incentives to cooperation rather than competition) to enhance these specific aspects, thereby fortifying the position of their countries within the TT ecosystem. We specify three complementary paths to achieve this. First, countries should prioritize establishing and enhancing robust digital infrastructure (Kirschning & Mrożewski, 2023), mainly through widespread and high-speed broadband connectivity, serving as the foundation for efficient communication and collaboration, crucial elements in successful TT. For example, implementing a nationwide initiative that expands and upgrades broadband infrastructure, ensuring high-speed internet connectivity reaching all regions, investing in smart city initiatives, and integrating digital technologies to create connected urban environments that facilitate collaboration and innovation.

Second, by empowering human capital with the necessary digital competencies, countries ensure that their citizens are well-equipped to engage in TT activities and navigate the complexities of the digital era (Bischoff et al., 2024). That is, launching comprehensive digital skills training programs for the workforce, focusing on emerging technologies, industry-specific competencies, and continuous learning, as well as facilitating partnerships between industries and educational institutions to align academic backgrounds with the evolving digital skill requirements of the workforce. Third and finally, maintaining adaptive and flexible policies is crucial (Anderson et al., 2023), allowing nations to stay responsive to evolving digital trends and sustain their success in the dynamic landscape of TT. For example, by introducing tax incentives, grants, and subsidies to encourage businesses to integrate digital technologies into their processes or instituting a regular review mechanism for digitalization policies, ensuring they remain flexible and adaptive to evolving technological landscapes.

The analysis presented in the paper also provides insights into the countries centrality and potential connections fragility within the TT network. Policymakers can leverage this information to enhance the overall resilience of the network by strategically reinforcing areas that may be more susceptible to fragmentation. By providing targeted support to regions identified as potentially fragile, public institutions contribute to the stability and sustainability of the TT ecosystem (Ferrer-Serrano et al., 2021). Public institutions are pivotal in strategically allocating resources to low-centrality countries identified through network analysis. Policymakers can direct financial support, infrastructure development, and technological resources to bolster these areas by targeting regions with lower connectivity and network centrality. This ensures that the benefits of TT are more evenly distributed, fostering inclusive growth and reducing disparities between high and low-centrality regions.

Finally, public institutions can be crucial in providing guidance and capacity building in regions where the network is at risk. This assistance can come in the form of training programs, workshops, and mentorship initiatives to enhance the capabilities of local actors in TT. Public institutions contribute to the long-term sustainability and effectiveness of collaborative efforts by empowering these regions with the necessary skills and knowledge. For example, policymakers can identify opportunities for promoting innovation hubs in the low-centrality areas. By strategically investing in the development of innovation ecosystems, public institutions can stimulate local innovation, attract talent, and create a positive growth cycle (Couñago-Blanco et al., 2024).

5.2 Limitations and future research avenues

Despite the advancements made in this research, it is important to acknowledge its limitations. The analysis conducted in this study aggregated all funded research projects from the inception of the Horizon Europe strategy up until the latest update in July 2022. While this provides a comprehensive overview of the TT on digitalization ecosystem during this period, it lacks a dynamic perspective and the ability to critically assess the continuity of the network strategy. To address this limitation, future research could expand the sample size and conduct a year-by-year analysis to capture the evolution of the network over time. Furthermore, future research could explore the individual level of analysis, focusing on collaborations between specific organizations. Such an approach may provide more detailed and nuanced insights, considering the unique characteristics that individual organizations bring to the collaboration. Additionally, this study focuses exclusively on Europe, omitting collaborations with countries outside the continent that may be of interest. However, given the limited number of projects involving countries outside Europe in the strategy, it is unlikely that their inclusion would significantly impact the main findings and conclusions of this research. Finally, it is important to note that this study does not establish causal relationships between the allocation of resources and their specific outcomes. Future work employing alternative methodologies to explore and establish these causal relationships would be valuable in furthering our understanding of the subject matter.

Appendix 1: List of countries included in the sample

Code	Country	Code	Country
AT	Austria	IS	Iceland
BE	Belgium	IT	Italy
BG	Bulgaria	LT	Lithuania
CH	Switzerland	LU	Luxembourg
CY	Cyprus	LV	Latvia
CZ	Czechia	MT	Malta
DE	Germany	NL	Netherlands
DK	Denmark	NO	Norway
EE	Estonia	PL	Poland
EL	Greece	PT	Portugal
ES	Spain	RO	Romania
FI	Finland	SE	Sweden
FR	France	SI	Slovenia
HR	Croatia	SK	Slovakia
HU	Hungary	UK	United Kingdom
IE	Ireland		

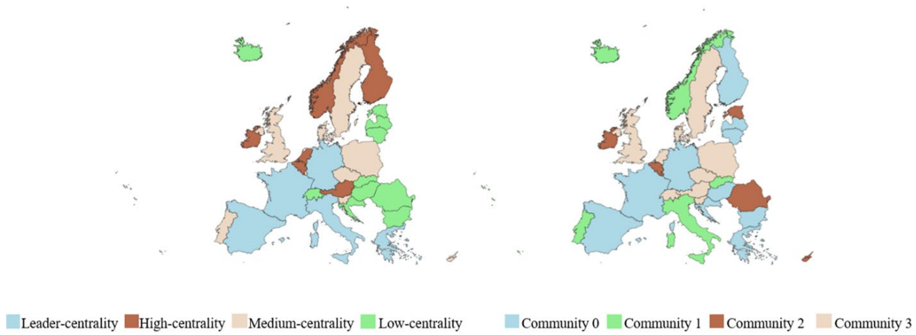
Appendix 2: Digitalization ranking according to the DESI index average (2021–2022)

Ranking position	Country	Value*
1	Denmark	67.29
2	Finland	66.38
3	Netherlands	64.87
4	Sweden	62.85
5	Ireland	59.93
6	Spain	57.79
7	Malta	57.67
8	Luxembourg	56.94
9	Estonia	54.83

Ranking position	Country	Value*
10	Austria	52.60
11	Slovenia	50.67
12	Germany	49.98
13	Lithuania	49.87
14	France	49.63
15	Belgium	48.51
16	Portugal	48.31
17	Latvia	47.92
18	Czechia	46.26
19	Croatia	45.31
20	Italy	45.05
21	Cyprus	44.17
22	Slovakia	41.70
23	Hungary	41.24
24	Poland	38.54
25	Greece	35.72
26	Bulgaria	35.16
27	Romania	29.01

*Value refers to the composite index of digital performance indicators, namely connectivity, human capital, integration of digital technology and digital public services

Appendix 3: Cluster map versus communities of modularity class map



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Declarations

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