Technological Forecasting & Social Change 184 (2022) 121873

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

The role of international networks in upgrading national innovation systems

Monika Petraite [a,*], Muhammad Faraz Mubarak [a,*], Rauleckas Rimantas [c], Max von Zedtwitz [a,b]

[a] School of Economics and Business, Kaunas University of Technology, Lithuania
[b] Dep't of Int'l Economics, Government and Business, Copenhagen Business School, Denmark
[c] Faculty of Social Sciences, Humanities and Arts, Kaunas University of Technology, Lithuania

A R T I C L E I N F O

Keywords:
National innovation system
Technological learning
Technology upgrading
International networks
Collaborative innovation networks
SEM-PLS modelling
R&D intensive firm
Central Eastern European Economy

A B S T R A C T

Technological learning within national innovation systems (NIS) stands at the core of technological upgrading at the firm and economy level. The common understanding is that NIS are the primary source of technological knowledge acquisition for innovating firms, but the opening of economies, the globalization of innovation networks, and the rapid internationalization of innovative firms challenge this view – especially with respect to small open economies in transition. We applied PLS-SEM to data from 131 R&D intensive firms responding to a survey investigating the mediating role of international networks for technological learning within Lithuania's NIS. The findings demonstrate a full mediating role of global innovation system networks in facilitating technological learning within NIS, partially contradicting the prevailing understanding of the primary importance of NIS based networks for firm learning. Technological learning of firms, and thus the upgrading of the NIS they are embedded in, relies more on international networks than previously assumed. These results call for a more careful design and facilitation of technological learning networks, recognizing global networks as a complementary and necessary component in NIS upgrading. This study contributes to the literature of technological learning within national innovation systems, with a special focus on R&D intensive firms leading the technological upgrading of a country's NIS.

1. Introduction

Research on transition and emerging economies has mainly focused on large economies such as China, India, Brazil and Russia, primarily because of the significance of these economies in the global community, the relative ease of conducting empirical research in large economies, and the availability of data in these countries. Small transitioning economies tend to be less well covered in terms of publicly available data and are less accessible to study (which makes subsequent research publication less likely). They have fewer means at their disposal to pursue national innovation policies. Because of their relative economic insignificance, they attract less interest from the public, including research funding. As a result, we know relatively little about the transition and technology upgrading mechanisms in smaller economies (Radosevic et al., 2019).

Given this bias in existing research, most of our assumptions about small country transitions are based on large country transitions. However, large countries differ from small countries in several ways relevant to their technological catch-up, including the presence of a large domestic market, large domestic variance of knowledge pools and economic conditions, and a greater variety of opportunities for economic and technological upgrading. Smaller countries do not have these characteristics and thus are more likely to be externally (i.e., internationally) oriented in their transformation. Simultaneously, several features of big transition economies are also evident in small transition economies, such as a relatively low level of trust in the country's bureaucracy and public institutions, a relatively low level of innovation (particularly in the early phases of the transformation) in comparison to rapid economic development, and widespread mistrust in the business community on how individual entrepreneurs will perform (as opposed

Abbreviations: NIS, National Innovation System; PLS-SEM, Partial least squares structural equation modeling; R&D, Research and Development; SME, Small and medium-sized enterprise; OI, Open Innovation; IS, Innovation System; AVE, Average Variance Extracted; CEE, Central Eastern Europe; OECD, Organisation for Economic Co-operation and Development; EFA, Exploratory Factor Analysis; CFA, Confirmatory Factor Analysis; VIF, Variance Inflation Factor.

* Corresponding authors.
E-mail addresses: monika.petraite@ktu.lt (M. Petraite), muhammad.mubarak@ktu.lt (M.F. Mubarak).

https://doi.org/10.1016/j.techfore.2022.121873
Received 1 July 2021; Received in revised form 15 June 2022; Accepted 10 July 2022

to seeking their luck in emigration).

In our research, we examine the role of the national innovation system-based networks in transforming the small-country economy through upgrading its technological and technological learning capabilities for innovation performance of firms operating in national innovation system-based networks. The concept of national innovation system (NIS) appeared in science, technology, and innovation studies in the late 1980s (Freeman, 1987; Lundvall, 1992; Nelson and Rosenberg, 1993). This framework suggested that the research system's ultimate goal is to facilitate innovation and acknowledged that the NIS is merely a component of a broader system that encompasses government, academia, industry, and the environment. The NIS concept also highlighted the linkages between the components or sectors as the "cause" of innovation systems' performance. However, we do not investigate the national innovation system per se in our study, instead we focus on firms operating in national innovation system based *networks*. R&D-intensive firms are considered as a vital source of economic growth based on technology upgrading (Radosevic et al., 2019), including foreign firms with inbound R&D investments in a country's innovation system as well as domestic firms' engagement in international innovation. Many Central Eastern European (CEE) economies are facing challenges in domestic technology absorption and their participation in global value chains (Radosevic, 2022), providing both the need and the opportunity to investigate technology learning in international networks.

The paper targets a continuing dialogue on national innovation systems-based networks (Freeman et al., 1982; Edquist and Lundvall, 1993), focusing on re-examining technology learning patterns in the post-soviet Eastern European context. Following Lundvall (2015), we define the national innovation system (NIS) as an open, evolving and complex system that encompasses institutions and economic structures, whereas the quality of its elements and the relationships between elements determine the rate and direction of innovation. Research on the knowledge and learning economy has emphasized learning within geographical proximities and knowledge spill-over effects on regional technological capability building. Lundvall (2015) noted that the relationships between users and producers are based on interactive organizational learning where the parties build channels for information transfer and develop a common language. Certain individual attributes, such as shared culture, shaped by common education and work experience, make it easier to interact among national borders. Empirical network analysis (Rothwell, 1994) showed that the networks most frequently mobilized for innovation were national rather than local or global.

In the context of open economies, the role of relationships is further amplified, productive interactions across divisional borders within the organization, external organizations such as suppliers, users, and knowledge institutions are considered as critical for open innovation success. Wang et al. (2012) revealed that open innovation (OI, Chesbrough, 2003) within national innovation systems-based network is linked to a country's specific context, that encompasses both, firm level capabilties, and system level capabilties. OI practices depend heavily on the internal capability of firms to leverage outbound and inbound knowledge and on the availability of sufficient external knowledge and other important resources. A well-equipped functional NIS largely determines the supply of external knowledge. This strong interdependence makes NIS more important than ever before. Open innovation is an emerging, collaborative, multi-actor, and multi-level process that involves business, government, research, and civil society (Radziwon and Bogers, 2019).

There is general consensus in the literature that it is the responsibility of firms to build robust and internationally competitive innovation systems. In their study of technology-intensive firms in Central and Eastern Europe, Radosevic and Yoruk (2012) found that the most important factors for innovation success were interaction with users, understanding of markets, and technological collaboration with other firms, confirming that firm innovation behaviour patterns were generally the same in rapid innovation driven transition countries as in developed innovative economies. However, given the complexity of innovation transactions, NIS and other innovation systems (IS) based technological learning can only take place under favourable socio-institutional conditions. Traditionally, the focus of study has been addressing formal institution, with less attention to the soft institutions, such as firms innovative capabilities, technological learning, dynamic capablities, and last but not least relational capabilties such as partnership managemnt and trust skills. In their study of 34 countries, Ghazinoory et al. (2014a,b) confirmed the strong positive effect of institutional trust and networking on entrepreneurship. Interpersonal trust and networks were shown to have a strong influence on knowledge development at the national level. Therefore, broader underlying contextual factors that are defined by societal rather than economic growth need to be considered when studying innovation and technology upgrading. Further studies by Brockman et al. (2018) established societal trust as a key factor in influencing the efficiency of open innovation. Post-soviet studies on trust – including institutional, business, and interpersonal trust – reveal specific conditions where higher international institutional trust is demonstrated compared to the national institutional trust (Audretsch et al., 2018) and weak institutional trust (Amorós and Bosma, 2013). Research on the role of national innovation systems on firm innovation behaviour has mostly neglected this vital component or addressed it indirectly, despite the acknowledged importance of technology learning within innovation networks. The principal question on how organizational capabilities associated with technology learning, knowledge exchanges, and trust for innovation impact the networking patterns within NIS environments remains open. However, in light of the relatively weak NIS performance within well-performing transition economies (in terms of general macroeconomic indicators), this issue raises critical importance.

Based on this problem formulation, we aim to discuss the role of international networks in upgrading national innovation systems-based networks built on research in a small CEE economy. The results highlight the importance of international business and innovation systems integration, especially in small transition economies. Large transition economies, also benefit from such international linkages but rely on a more extensive arsenal of assets and opportunities in leveraging domestic and global capabilities. This realization has significant implications for policy making in small transition economies regarding opening up their economy to foreign investment, allowing domestic actors to tap into global markets and resources, and long-term strategy development in domestic companies for technological and organizational upgrading. Future research will need to qualify better the effect of the international contribution for small transition economies (e.g., which resources and assets matter most) and the sources of international partners and competitors (e.g., whether those are from other large transition economies or already advanced industrialized economies countries).

This study fills a research gap by focusing on technological learning and compund role of trust in upgrading national innovation systems through international networks – empirically investigated in the context of Lithuania, a small CEE economy on the European periphery, which has demonstrated rapid eonmic growth, and reached the level of highly developed economies in 20 years of development (WB, 2022) under generally undermined trust in institutions, systems, and also societal trust by post-soviet legacy and is demonstrating the transition towards innovation driven growth in the recent decade.

Analysing the results of a survey of 131 firms in the small transition economy of Lithuania with SEM-PLS, we find that the linkages of domestic firms with the international community (in terms of access to international business networks, to global innovation systems based networks, and through domestic foreign competition and presence of foreign innovation actors) are significantly more critical for the development of the national innovation system-based firms' network than predicted by large economy transition research. Domestic organizational and technological knowledge is inconsequential for the improvement of the national innovation system-based network unless associated with the international networks and competition; we interpret these findings as a technology learning and associated trust benefit granted to international experience (in the case of domestic firms operating in a global context) and international reputation (in the case of foreign competitors operating domestically). Furthermore, innovation performance, productivity, and success are highly influenced by user networks – i.e., communities in which domestic and international actors pursue innovation within shared markets or platforms – and again neutral concerning national innovation systems-based network otherwise.

The paper is structured as follows. The first part discusses the theoretical underpinning of technology learning and its manifestation in various innovation networks, especially national and global innovation systems based and value chain-based networks. We also develop the hypothesis for empirical modelling of the mediating role of international networks for technological learning within the national innovation system based networks. The second part of the paper focuses on the research methodology (survey-based data collection on innovative firms within a small open economy), data presentation, hypothesis testing using SEM PLS modelling, and analysis. Finally, we provide key findings, discussion and implications.

2. Literature review and hypothesis development

2.1. Firms internationalization strategy and technological learning

Dodgson (1991:110) defines technological learning as "the ways firms build and supplement their knowledge-bases about technologies, products, and processes, and develop and improve the use of the broad skills of their workforces." In contrast, Kim (1997) uses technological learning simply to depict the dynamic process of acquiring technological capability. Hitt et al. (2000) suggested that "technological learning is linked to the firm's ability to develop, maintain and exploit dynamic core competencies" which are related to technology. Therefore, technological learning is the development of knowledge about technologies, products and processes while developing the competencies in order to enhance technological capabilities.

Technological learning enables technology-driven companies to acquire and sustain knowledge (Simpson et al., 2001) both for competitive advantage and for developing entire emerging industries. For instance, Dodgson (1991) describes the learning characteristics of a leading European biotechnology company, Kim (1997) investigates both macro and micro levels of analysis to explain the dynamics of learning in several highly successful Korean technology-based industries, and Carayannis (2000) identifies learning practices used by US and European companies that have demonstrated long-term success and prosperity in a variety of technology-driven sectors. Other research emerging in the 1990s highlighted the importance of learning in high-tech or technology-driven industries (Hitt et al., 2000; Ernst, 1998; Kazanjian et al., 2000; Hobday, 1994; Bohn, 1994; Zahra et al., 2000).

At the level of international networks, knowledge and learning are seen as sources to compete globally and considered at least as valuable as physical assets if not more (Barney, 1991; Grant, 1996; Sanchez and Heene, 1997; Conner and Prahalad, 1996). The notion of technological learning also implies an ongoing and interactive process that can accommodate the emerging, unexpected characteristics of innovation and new knowledge creation. The interactions among all the actors of an innovation system are fundamental sources of knowledge and learning in the system and constitute an essential part of the innovation process (Lundvall, 1992; Malerba and Nelson, 2011).

Simpson et al. (2001) reiterated that it is of utmost importance for technology-driven companies to have relationships with customers, suppliers, users, and other external partners, and to learn from their experiences via their inclusion in collaborative innovation networks. These relations lead to learning by interaction where trust is established and eventually reinforcing the interaction with stakeholders, which is essential for firms to innovate with external partners. Additionally, Simpson et al. (2001) confirmed that innovative firms establish relationships with innovation-based partners, such as external research institutes or universities, to learn from them. Furthermore, the knowledge obtained from external sources and partners is utilized by integrating it into their processes, products, and services (Simpson et al., 2001; Mahmood and Mubarik, 2020). In a nutshell, technological learning can be acquired from various actors such as technology developers, suppliers, lead users, industry associations, service providers, and multiple networks and their connections (Musiolik and Markard, 2011; Musiolik et al., 2020).

In a globalized economy, innovation processes and industrial dynamics depend on multi-level networks that transcend traditional spatial and sectoral boundaries (Hipp and Binz, 2020). Innovation is a dominant form of knowledge production and learning, represented as either science-technology-innovation (STI) or doing-using-interacting (DUI). STI-based knowledge is highly analytical and depends upon formalized, lab-based R&D. Since this form of knowledge can be codified into patents, papers, blueprints, etc., it is relatively easily transferable in space (Hipp and Binz, 2020).

Modern products are developed with technological knowledge from a diverse set of actors and industries distributed worldwide (Stephan et al., 2017). Studies have shown that a more internationalized and cross-sectoral perspective helps to efficiently achieve national/regional industrial development and innovation objectives (Graf and Kalthaus, 2018; Beuse et al., 2018; Grau et al., 2012). This perspective could improve firms' technological learning, as they seem to experience increasingly fast reconfiguration for innovations when they are embedded in international or global structures (Dewald and Fromhold-Eisebith, 2015; Binz and Truffer, 2017; Lee and Malerba, 2017).

The determinants of innovation and technological learning do not only reside in organizations and their local innovation systems (NIS) based networks (Pan et al., 2018; Jacobsson and Bergek, 2011), they are also located in broader and even international innovation systems. In order to be part of such international innovation-based networks, firms need to devise strategies to internationalize their innovation to improve their local/domestic innovation system.

The sectoral configuration of the industry consists of a technology value chain and all actors that produce these technologies, often from different sectors that supply key inputs or intermediary goods (Malerba, 2002; Hipp and Binz, 2020). This technology value chain contributes to improving technological learning at each step by providing critical tangible and intangible inputs (Stephan et al., 2017). Similarly, firms engaged in the global value chain can influence the other firms through knowledge spill-overs which enhance their technology-related learning (Hoppmann, 2018). Some parts of the value chain may depend on sectoral configurations and supportive innovation system structures where standardized knowledge, international mass markets, and fierce price-based competition play a key role (Hipp and Binz, 2020). In summary, the technological learning of firms is increased by playing a role in international innovation networks, which can be achieved by pursuing an innovation internationalization strategy. We call this type of internationalization as innovation development strategy whereby NIS networks are developed with the help of internationalization. Against this backdrop, we formulate our first hypothesis as:

Hypothesis 1. Innovation development strategy enhances technological learning.

2.2. Technological learning and international networks

Literature on innovation studies has analysed the combination and recombination of previously unconnected ideas that generate new knowledge and, ultimately, technological innovations (Aghion et al., 2009). These technological innovations are achieved through technological know-how (or learning), which are acquired through internationalization (of innovation) strategy, including geographic terms which leads to diffusion of innovation in the shape of knowledge-spill overs (Audretsch and Feldman, 1996; Tojeiro-Rivero and Moreno, 2019). Technology learning also affects the networks of international research and cooperation between various firms and stakeholders. Global innovation systems (GIS) based networks acknowledge the importance of technological learning to achieve technical innovations.

Firms strategically shape the innovation and technological development in these networks by setting new technical standards (Garud et al., 2002), enhancing business models (Kaplan and Murray, 2010), introducing or learning new practices (Maguire et al., 2006). These elements strengthen the network by providing positive externalities to foster the fabric of innovation, locally and globally (Musiolik and Markard, 2011). Inter-organizational networks have been recognized as facilitators of interactive learning and knowledge generation (Lundvall, 1992; Ozman, 2009). A systematic analysis of formal networks, incl. inter-organizational structures, where firms and other actors come together to achieve common aims, is essential to understand processes of innovation system-based networks building better. Trust is a crucial component for knowledge and technology learning (Musiolik and Markard, 2011). Shaikh and Levina (2019) found that the presence of trust, commitment, and reputational complementarity is vital for business networks & alliances and R&D networks which are formed to enhance technology learning.

Musiolik and Markard (2011) found that German firms paid particular attention to building trust and reputation. Their efforts cascaded the actions to improve communication in the collaborative knowledge networks. When the trust was increased, they could sign further projects with the partners and actors in international networks, including user networks, R&D networks, and competitors. Nevertheless, similar arrangements were succeeded with their competitors, which later became coopetitors. Consequently, their relationships in the international network became more robust and more stable. Hence, we argue that along with technological learning, the element of trust can positively impact the international networks towards improving the innovation of networks member domestically.

2.3. International networks and national innovation system based networks

An innovation ecosystem is the evolving set of actors, activities, and artifacts. The institutions and relations, including complementary and substitute relations, are essential for the innovative performance of an actor or a population of actors (Granstrand and Holgersson, 2020). In innovation studies, the concept of innovation systems has been widely used, often with different qualifiers such as national innovation systems (Freeman, 1987; Lundvall, 1992) or sectoral innovation systems (Breschi and Malerba, 1997). The late 1980s saw the emergence of a new and more systemic understanding of innovation and diffusion processes. The resulting "National Innovation System" framework (Lundvall, 1992; Nelson and Rosenberg, 1993; Freeman, 1987) has attracted significant attention among both researchers and policymakers, resulting in the increased importance of the larger field of Innovation Systems (IS) research (Rakas and Hain, 2019). Subsequent research generated a cascade of different IS frameworks differing in their analytical and conceptual focus, highlighted elements and dimensions, system boundaries, and units of analysis, such as regional (Cooke, 2001; Malmberg and Maskell, 2002), sectoral (Breschi and Malerba, 1997; Malerba, 2002, 2005), technological (Carlsson and Jacobsson, 1997; Bergek et al., 2008; Hekkert et al., 2007), business (Whitley, 2000), and social systems of innovation and production (Amable, 2000), as well as national systems of entrepreneurship (Acs et al., 2014). Its community of users has expanded along the same lines as researchers from adjacent fields have become interested in a systemic approach to studying innovation. The main thrust of the NIS approach is that innovation and technical change are the outcomes of a complex pattern of interactions among a wide variety of actors such as firms, universities, and government research institutes. The NIS literature argues that the interactions within national boundaries are the most relevant (Cirillo et al., 2019).

Various types of international networks have been considered as drivers of firm performance, which further influences local innovation systems (Laursen and Salter, 2006; Nieto and Rodríguez, 2011). Nevertheless, they enable firms to acquire external knowledge at the local level and through building pipelines to benefit from knowledge hotspots worldwide (Bathelt et al., 2004; Tojeiro-Rivero and Moreno, 2019). The tendency to acquire external knowledge through mechanisms such as cooperation agreements or outsourcing is a strategy to become more innovative by leveraging knowledge external to the firm; it also helps to overcome shortcomings due to a purely internal structure/way of thinking of the enterprise (OECD, 2008).

Empirical evidence has shown that different networks play different roles in forming an innovation system, and they depend on different kinds of resources to achieve their goals. Some networks rely mainly on the resources of their members, while others develop a broad range of network resources. The German company IBZ, for example, utilized a variety of network resources and influenced its National Innovation Program as well (Musiolik et al., 2012).

Networks can also be based on established organizations and use the resources primarily already available in these organizations. The underlying strategy is to identify complementary resources of different actors, combine them (through the membership of the actors that control them) in a network, and apply them directly towards the network goals (Musiolik et al., 2012). Strong international networks are essential in this scenario as they enable the assimilation and utilization of complementary resources among actors, thus accelerating innovation (Musiolik et al., 2012; Carlsson and Jacobsson, 1997).

In this way, the international networks help to develop the resources of participants/stakeholders by enabling the collaboration between the actors/firms having common strategic interests and goals. In doing so, they exchange their tangible and intangible resources - including premises, technology, knowledge, and expertise - in order to achieve synergic outcomes. Furthermore, with the increasing interactions and cooperations with each other, firms tend to trust their exchange partners which enhances reputation of networks that ultimately improves the networks including international and domestic ones. In their research, Musiolik et al. (2012) reported that collaborative knowledge interactions of firms taken place in innovation networks improved the domestic innovation system in the German context. Hence, the inclusion/participation of firms in innovation networks can upgrade technological learning in the national innovation system based networks of a country through trust building and reputation enhancement.

Many studies have provided empirical evidence that networking strategies positively and significantly impact innovation performance (Nieto and Rodríguez, 2011). On the one hand, collaborative research with a broad range of partners may enable innovating firms to acquire the required information from various sources, leading to more synergies and intake of complementary knowledge, thus promoting innovation performance. In this sense, collaboration with other organizations is necessary to solve new problems for which the market does not have a proper solution, leading to more interactions among organizations (Tojeiro-Rivero and Moreno, 2019). This kind of strategy requires face-to-face contacts, reducing the likelihood of appropriation of some specific ideas/projects because both enterprises know each other's projects while building a relationship of trust. At the same time, collaboration may give access to more intangible and tacit knowledge and know-how not easy to spill over. Indeed, previous literature has recognized that cooperation embeds a complex/technical knowledge structure related to the appearance of new types of problem-solving requirements (Teirlinck and Spithoven, 2013).

Firms also build strategic alliances with other local and international firms with the intent of tapping into partners' resources and capturing long-term value from these relationships. Such partnerships are typically governed by contractual or equity arrangements with clear mutual obligations. Organizations have begun to seek strategic alliances with open innovation communities (Shaikh and Levina, 2019). These alliances enable firms to tap into resources more quickly than the competition and innovate by combining diverse sources of expertise (Hoang and Rothaermel, 2005) compels organizations to look beyond their boundaries (Parmigiani and Rivera-Santos, 2011; Lorenzoni and Lipparini, 1999). Following this mindset, companies, especially technology firms, increasingly embrace open innovation communities as part of their innovation strategy (Dahlander, 2007; Greenstein and Nagle, 2014; Dahlander and Gann, 2010); the decision of which communities to partner with is becoming more important as these alliances cover joint R&D and marketing activities, mutually complementary technology assets and skills, and joint standard-setting. The open and user innovation literature shows that firms that engage with open innovation communities over the long term often share very similar aims (Afuah, 2018; Von Hippel, 2005).

But firms also partner with communities in order to innovate on specific tasks, e.g., by tapping into the resources that they are missing internally (Afuah and Tucci, 2012; Felin and Zenger, 2014) but for which they have a relevant absorptive capacity (Lichtenthaler and Lichtenthaler, 2009), complementary IP (Lakhani and Lonstein, 2011), and access to markets (Vanhaverbeke et al., 2008). The literature argues that these complementary resources enable partners to capture the value generated by their relationship with the community. Besides value creation, relations in a business network help foster new ties through trust-building mechanisms, potential partners' global and local reputations, and social network position (Carson et al., 2006).

In recent years, there has been some criticism and questioning of the relevance of a (nationally bounded) systemic approach to innovation in a world characterized by increasingly globalized value chains (Pietrobelli and Rabellotti, 2009; Szapiro et al., 2016; Mubarik et al., 2021; Wan et al., 2022). However, it is equally essential to develop the local system of innovation as well. Therefore, it is pertinent to explore how networks can play their part in creating or improving NIS. Thereby, we regard GIS, user networks, business networks & alliances, foreign lead users, and R&D networks as part of an international network. In a nutshell, technological learning improves the international innovation networks that further enhance the NIS. Thus, we formulate the following hypotheses:

Hypothesis 2. Technological learning and trust has a positive impact on National Innovation Systems based networks.

Hypothesis 3. International networks mediate technological learning and trust within National Innovation Systems based networks.

2.4. Operational model

The research model of our study posits that innovation internationalization strategy enhances technological learning and trust in networks, which further improves the NIS. We test its manifestation in the NIS networks, where international innovation networks are taken as mediators. Innovation development strategy is an independent variable that positively improves technological learning and trust as Hypothesis 1 (H1). Technological learning and trust also mediate the relationship between innovation development strategy and NIS, mainly by enhancing NIS, as Hypothesis 2 (H2). International innovation networks are mediating the relationship between technological learning & trust and NIS, as Hypothesis 3 (H3). In doing so, we have tested the hypothesis explained and highlighted in the operational model of research given below in Fig. 1.

3. Methodology

In this study, the case of a CEE country – Lithuania – is taken for analysis as a low trust economy context. The post-soviet contexts (with few exceptions) form a high level of mistrust due high corruption level and at least partial institutional inefficiency (WEF, 2022; WB, 2022). Still, the economies are demonstrating sufficient growth and vitality, with relatively moderate innovation performance demonstrated by national innovation systems. After over 30 years of free economy, Lithuania has transitioned from the post–soviet economy of a low-income country with labour intensity driven competitiveness towards a productivity and innovation driven economy as indicated by high average income, innovation driven exports, and high economic freedom (WEF, 2022). Lithuania joined the EU in 2004, which provided an opportunity for international trade and value chain integration and resulted in high openness of economy and trade ranked 15th by World Bank (WB, 2022). Current development marks an important transition stage from productivity driven to the innovation driven economy, which is taking a particular pattern from the firm's behaviour and technology capability building perspective. This forms our case study context for hypothesis testing.

In particular, we explore the link between firm's innovation internationalization (strategy), technological learning & trust and a combination of various networks employed in order to benefit from the domestic innovation systems based on a survey of innovative firms in Lithuania and applying partial least squares structural equation modelling (PLS-SEM) as a data analysis method. The sampling technique for this primary data collection followed probability sampling, more accurately, stratified random sampling, dividing the population based on the sector classification in NACE Rev. 2 for statistical classification of economic activities in the European Community.

The analysis is thus based on primary data of 131 innovative firms from Lithuania's private sector. The data analysis methodology involved two steps: first, formation and verification of the variables via factor analysis; second, the formation of complex cause-effect relationship model and testing hypotheses via PLS-SEM. For the analysis of the domain dimensionality, the exploratory factor analysis (principal component analysis) was conducted for each construct domain and one or several meaningful dimensions were identified. When used as a data analysis method, SEM reveals the structure of causal paths relating constructs (latent variables), and specifically PLS, or variance-based SEM, helps to deal with the problems in traditional covariance-based SEM including problematic measurement model identification when

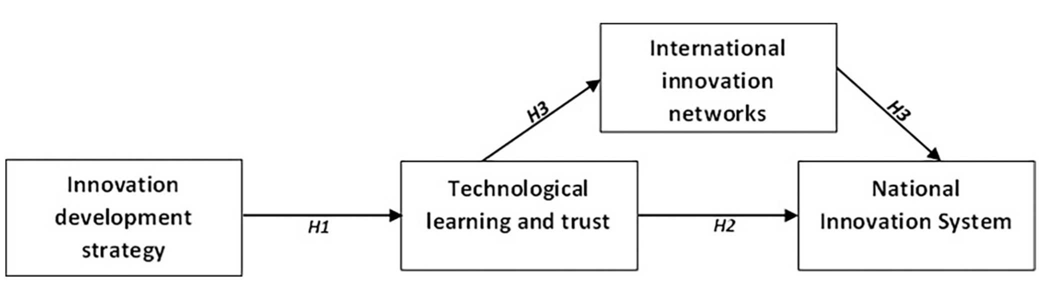

Fig. 1. Operational model of study.

models are complex and sample sizes are relatively small (Hair et al., 2011). The estimation of the structural model in PLS-SEM is similar to OLS regression and therefore rules of thumb that require from 10 to 30 cases per independent variable suggest that >10 independent variables (incoming arrows representing causal direction) can be included at any part of the model for a sample of 131 cases. Despite its seeming linearity, the model encompasses high number of different paths that lead to ("cause") latent variables. The model became even more complex when we introduced the structure among latent variables in the *strategy* and *network* domains and additional theoretically relevant mediation effects were introduced, e.g., what types of partner networks lead to global versus national innovation systems. Given this *ex-ante* imposed structure we refined the model by removing the statistically non-significant causal arrows one by one to arrive at a clearer, more parsimonious model.

3.1. The quality of the measurement and structural models

To assess the convergent and discriminant validity, we conducted item and construct level analysis. As the measurement model was based on EFA, we do not expect large cross-loadings across latent variables or very low loadings on relevant latent variables. However (Table 1), three manifest variables do not conform to the rule that for exploratory analysis, loadings should be at least 0.60 (for confirmatory research 0.70), as well, in four manifest variables the second largest cross-loading fails to be less by 0.20 as compared to the loading on the relevant latent variables (although close to the threshold). High cross-loadings among the latent variables representing types of partners were expected, therefore we do not see a problem here given that loadings are higher by at least 0.20 from the highest cross-loadings. That said, we have used this configuration of latent variables for our analysis for the reasons of content validity and then rechecked the calculations with the problematic mediating variables removed: the results were substantially the same as path coefficients changed by 0.05 at most and their statistical significance in the structural model remained the same.

At the construct level, the Fornell-Larcker criterion requiring the square rooted average variance extraced (AVE) to exceed a correlation with any other construct is established, as the largest correlation coefficient is below 0.70 and the minimum square rooted AVE is above 0.70 (Appendix A).

Analysing the quality of measurement model at the latent variable level, the internal consistency reliability of the scales is above the 0.70 threshold, and the AVE of latent variables stands above 0.50 (Table 2) which are within the threshold recommended by Hair et al. (2011). For the final structural model, the quality measures are coefficients of determination (R-squared), redundancy (product of AVE and R-squared: the amount of variance in an endogenous construct explained by its independent latent variables, see Sanchez, 2013: 68–69) show that in average 19 % of variance in latent variables is explained (R square values) and MVs explain in average 13 % of variance of endogenous latent variables (redundancy estimates).

Predictive relevance scores (Stone-Geisser's Q2 value) for different omission distances (d) values show that the construct of international business networks and alliance is negative which indicates that for this latent variable the path model is not relevant in terms of predictive accuracy (Hair et al., 2014: 183–184) and its data cannot be reconstructed by using the PLS model parameters (Fornell and Cha, 1994; Shmueli et al., 2019). Therefore, this latent variable is included into our final model for presentation purposes but could as well be excluded from the model as no other latent variable predicts it adequately. Other than this construct, all values are positive and within the prescribed threshold required for predictive relevance.

Furthermore, the Goodness of Fit measure (GoF) that is based on communalities (AVE's) and R-squares is 0.36, which is a threshold value for a large effect size (based on Cohen, 1988 suggested effect sizes of R-square). Thus, the final model has a good fit with the data.

4. Key findings

Given that the measurement model is valid we can turn to the results of the structural model, i.e. statistical significances and sizes of the path coefficients (Table 3 and Fig. 2).

In general, if we relax our expectations regarding statistical significance level, Innovation development strategy (IDS) does have a direct effect (0.39) on Technological learning and trust (TLT) (0.15). Further, TLT exerted a positive impact (0.38) on International competitors and foreign lead user networks (ICUN). Also, a positive impact of TLT on International user networks (IUN) (0.24), and on National R&D networks (NRD) (0.23) is found. However, Global innovation systems (ISN) (0.2) and International business networks & alliances (IBNA) (0.14) are not reasonably influenced by TLT. Interestingly, ISN mediated TLT with National innovation system network (NIS) at comparatively higher levels (0.43) than other networks. Likewise, IBNA also mediated this relationship at a comparatively low amount (0.21). As ICUN were highly impacted (0.38) by TLT, however, they surprisingly failed (−0.34) to mediate it with NIS network. IUN and NRD network mediated TLT and NIS network at 0.25 and 0.31 respectively. As expected theoretically, no direct impact (0.11) of IDS is found on TLT, and the variety of international networks mediated between TLT for improving NIS network.

From the analysis of the measurement model, we may expect the types of partner networks to be highly interrelated (but not too high, as the VIF's are not higher than 2) and therefore most of the direct path coefficients relating these types are statistically significant ($p < 0.05$). Within this linear view of the process that was set out in our initial model, some mediating effects are observed and should be given a substantial interpretation. First, TLT do not directly relate to NIS network as both path coefficients are close to zero and non-significant, but are mediated by other types of networks including ICUN, IUN, and NRD networks. Second, IDS does not directly impact NIS network. This relationship is mediated by TLT and a variety of networks. The modelled relationships are shown below in structural model Fig. 2.

Table 1
Intercorrelations among latent variables (Spearman's rho cor. coef., $n = 131$) versus square root of AVE.

Labels/variables	AVE sq. root	Max correlation	IDS	TLT	ICUN	IBNA	ISN	NRD	NIS	IUN
Innovation strategy - IDS	0.742	0.568	1.000							
Technological learning and trust - TLT	0.768	0.496	0.213*	1.000						
International competitors and foreign lead users based networks - ICUN	0.831	0.643	0.253**	0.090	1.000					
International Business based networks and alliances - IBNA	0.860	0.676	0.177*	0.108	0.643**	1.000				
International innovation system based network - ISN	0.806	0.676	0.247**	0.097	0.605**	0.676**	1.000			
National R&D based network - NRD	0.837	0.629	0.206*	0.290**	0.482**	0.462**	0.298**	1.000		
National Innovation System based network - NIS	0.819	0.629	0.089	0.170	0.519**	0.394**	0.413**	0.629**	1.000	
International User based networks - IUN	0.721	0.501	0.276**	0.214*	0.350**	0.404**	0.501**	0.429**	0.391**	1.000

* $p < 0.05$.
** $p < 0.01$.

Table 2
Quality characteristics for latent variables.

Labels	Number of reflective MVs	Communality (AVE)	CR (Dillon-Goldstein's rho)	R-squared	Redundancy	Q-squared, d = 5	Q-squared, d = 10
Innovation development strategy - IDS	4	0.55	0.83	0.293	0.170	0.152	0.148
Technological learning and trust - TLT	4	0.59	0.85	0.145	0.085	0.062	0.058
International competitors and foreign lead users based networks - ICUN	7	0.69	0.94	0.032	0.022	0.009	0.011
International Business networks and alliances - IBNA	5	0.74	0.93	0.042	0.031	−0.009	−0.001
International/global innovation system-based network - ISN	6	0.65	0.92	0.562	0.367	0.315	0.324
National R&D network - NRD	3	0.70	0.87	0.141	0.098	0.035	0.043
National Innovation System based network - NIS	3	0.67	0.86	0.435	0.293	0.230	0.254
International User based networks - IUN	3	0.52	0.76	0.285	0.149	0.123	0.125

Table 3
Estimates and confidence intervals for path coefficients in the structural model.

Path	Estimate	Bias	Std. Error	90 % lower	90 % upper	Sig. 90 %	95 % lower	95 % upper	Sig. 95 %
IDS → TLT	0.39	0.03	0.09	0.182	0.501	*	0.182	0.516	*
TLT → ISN	0.20	0.01	0.12	−0.025	0.369		−0.048	0.398	
TLT → IBNA	0.14	0.02	0.08	−0.025	0.246		−0.041	0.263	
TLT → ICUN	0.38	0.02	0.09	0.138	0.480	*	0.122	0.508	*
TLT → IUN	0.24	0.01	0.11	0.038	0.417	*	0.020	0.472	*
TLT → NRD	0.24	0.02	0.09	0.018	0.337	*	0.012	0.357	*
IDS → NIS	0.11	−0.01	0.07	0.009	0.239	*	−0.007	0.261	
ISN → NIS	0.43	−0.01	0.09	0.302	0.591	*	0.287	0.648	*
IBNA → NIS	0.21	0.01	0.09	0.069	0.344	*	0.046	0.372	*
ICUN → NIS	−0.34	0.01	0.11	−0.576	−0.202	*	−0.605	−0.173	*
IUN → NIS	0.25	0.00	0.10	0.081	0.436	*	0.059	0.466	*
NRD → NIS	0.31	0.00	0.07	0.200	0.450	*	0.170	0.482	*

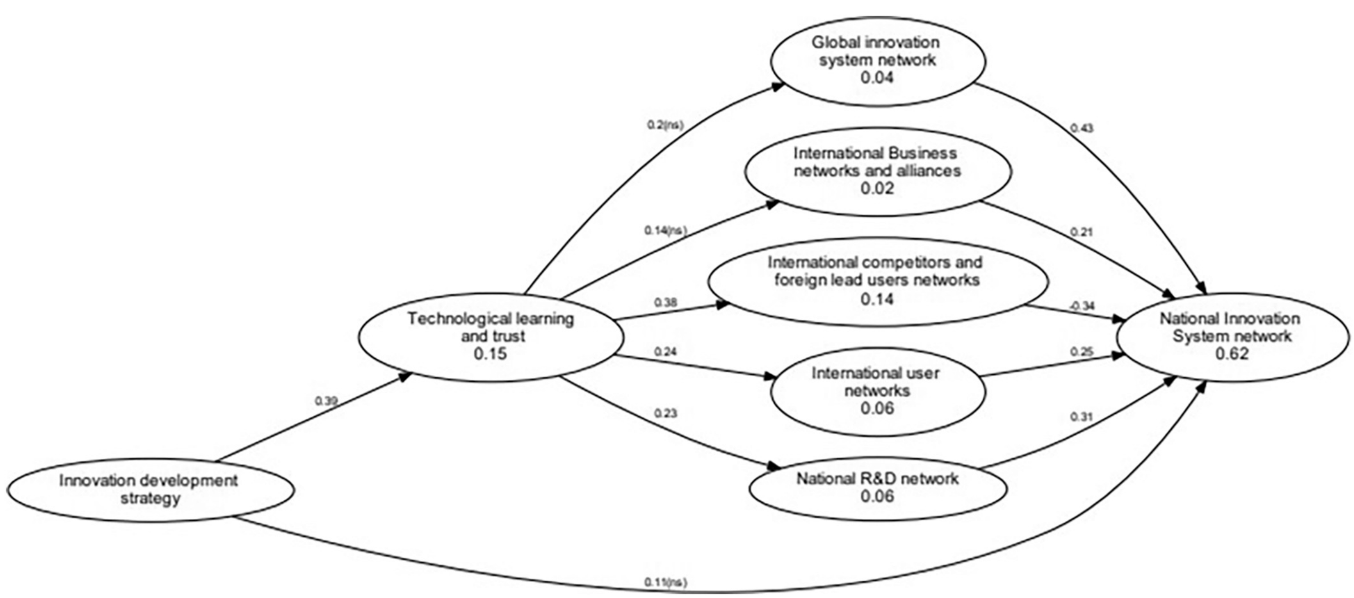

Fig. 2. Structural model: the mediating role of international networks in upgrading national innovation systems capabilities.

5. Discussion and conclusions

The hypotheses tested are based on the typology of firms' innovation development strategy, technology learning and interfirm trust, and underpinning engagement in innovation networks that lead to the success of NIS based networks. PLS-SEM is used to explain the evolving technological learning patterns within and across the complexity of innovation systems and variety of stkeholders.

The modelling revealed that innovation development strategy leads firms towards different approaches in network formation in order to achieve innovation development goals resulting in different innovation networks' constellations. In this interplay, the innovation development and internationalization strategy of firms combined with the strong internationalisation focus directly influenced the pattern of technological learning network formation within the global innovation systems through international user networks, national R&D networks, global innovation system networks, and international business networks and alliances that mediate the engagement within the national innovation system at the final step. No direct effect of internationalization and innovation development strategy was found on the NIS network.

Surprisingly, technological learning and trust only insignificantly impacted the global innovation system based networks. However, it further mediated the engagement of technological learning and trust development within the NIS network at the highest level compared to other networks studied. It indicates the inherent ability of the global innovation system networks to improve domestic innovation systems, a finding which echoes the results of Laursen and Salter (2006) and Nieto and Rodríguez (2011). Likewise, international business networks & alliances were only marginally affected by technological learning and trust. Still, it reasonably mediated with the NIS network, which is in line with the study of Tojeiro-Rivero and Moreno (2019), who contemplated the role of international business networks to develop the local or national innovation network. International user networks and national R&D networks also mediated technological learning and trust within NIS networks with the amount of stimulus they received from technological learning and trust. In this particular context, we may refer to these as appropriate variables (mediators) that transmit their influence to develop a national innovation system in line with the view of Musiolik et al. (2012).

The key findings highlight a few vital firm behaviour patterns informing technological and innovative capabilities in Central and Eastern European country transitions towards innovative economies:

1. Technological learning and trust are critical organizational capabilities for executing innovation strategies within networks to succeed in national innovation systems. Trust is a capability which (indirectly through the mediation of international networks) improves innovation in NIS networks.
2. While technological learning and trust are critical factors in forming complex innovation networks, they impact national R&D and innovation systems mostly in the context of global innovation systems, international user networks, national R&D networks, international competitors & foreign lead users, and international business networks & alliances.
3. Internationalization and innovation development strategies do not directly drive or improve the domestic innovation system. They achieve this objective through the mediation of technological learning, trust, and various innovation networks.
4. The effects to national innovation system based networks have to be fully mediated by either international business networks, global innovation systems based networks, or international competitor and user networks, depending on innovation strategy and organizational capability employed.
5. User-driven innovation network engagement is the only factor directly impacting and also fully mediating innovation success. There is no direct impact on innovation success from any other innovation network analysed. However, its effects need to be amplified via complex knowledge and learning interactions mediated via national innovation systems or international lead user and competitor networks.

6. Limitations and future research directions

The limitations of the research stem from the research scope and focus, i.e. the entire study has specifically targeted innovative firms from small open economy that faces innovation driven growth challenges, namely Lithuania. In addition to that, the study encompassed R&D intensive SMEs only that shape a specific behavioural patterns and demonstrate higher innovation capabilities, including open innovation as compared to the general sample. We would like to draw the attention to the small size of economy that in combination with the diversity of the technological knowlede desired and the pressure of rapid internationalisation due to limited or absent domestic demand force firms to develop international networks at the very early development stages. The similar tendency has been approached at the level of regional innovation systems and cluster studies (Radziwon and Bogers, 2019). The studies have highlighted the importance of soft skills, especially trust for technological learning across domains, where geographical and cultural proximity plays and important role. Still, technolgical proximity remains dominant variable, and our study did not explicitly addressed it. Therefore the role of technological proximity in combination with the mediating role of international innovation networks in upgrading national innovation systems shall be further studied. The role of societal trust in open innovation has been proven to be of critical importance for innovation driven economies (Brockman at al., 2018), however in the domain of internationally embedded R&D intensive SMEs it can be replaced by the innovation network based trust that reaches outside of national borders. Central Eastern European economies still feature some similarities as it relates to societal trust, however the landscape is rapidly changing in CEE and Europe at large, and the interfirm trust component in relation of societal trust shall be further studied for deepening the understanding of technological learning and upgrading at the NIS level.

7. Implications of study

Technological learning within national innovation systems is defined by the quality and diversity of networks of an innovation. This implies the need at the policy level to draw higher attention to the facilitation of diversity of innovation networks, including user driven innovation networks, international innovation alliances, global innovation systems, value chain based networks, and other more traditional international R&D networks. As the success of the upgrading of national innovation systems depends on the success and direction of international innovation network embededness, technological learning at the global scale should be facilitated by direct and indirect policy measures, and include direct support to network formation, but also multinational and multicultural collaborative innovation skills. These extends far behind team diversity management, as institutional components play an important role as well, including informal and formal institutions. Foreign network formation requires a diferent set of open innovation and networking skills (Podmetina at al., 2018) that needs to be developed at the firm level in order to enable succseeful international network based technological learning. Knowledge transfer to SMEs is meaningful only when it is thoroughly connected to the innovation activities taking place within a smaller business. Hence, any meaningful knowledge transfer for SMEs requires a better understanding of innovation activities and capabilities within these organisations. The SMEs' innovation activities are an amalgamation of technology adoption, product and process development, and intensive marketing activity. Moreover at the firm level, innovation capabilities development should focus on strategic innovation partnership management and networking capabilities along with the development of dynamic capabilities, as well as trust management. Together with innovation absorptive capabilities, larger attention needs to be given to relational and transformative dimensions of technological learning, the networks of innovation, innovative culture, innovation behaviour, dynamic capabilities, intellectual capital, and several others. In addition, these capabilities should be investigated in the variety of collaborative innovation networks including open innovation networks, digital networks, multisided platform based networks, etc. The development of such capabilities will not only increase technological learning within these networks but also lead to further improvement of national or domestic innovation system networks of a country.

Acknowledgement

This project has received funding from the Research Council of Lithuania (LMTLT), agreement No S-MIP-19-44) and has been performed in cooperation with the European Union's Horizon 2020 research and innovation programme under grant agreement No 810318. We would like to thank Prof. Slavo Radosevic (University College London, UK) for his valuable comments on the paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2022.121873.

References

Acs, Z.J., Autio, E., Szerb, L., 2014. National systems of entrepreneurship: measurement issues and policy implications. Res. Policy 43 (3), 476–494.
Afuah, A., 2018. Crowdsourcing: a primer and research framework. In: Tucci, C.L., Afuah, A., Viscusi, G. (Eds.), Creating and Capturing Value Through Crowdsourcing, pp. 39–57.
Afuah, A., Tucci, C.L., 2012. Crowdsourcing as a solution to distant search. Acad. Manag. Rev. 37 (3), 355–375.
Aghion, P., David, P.A., Foray, D., 2009. Science, technology, and innovation for economic growth: linking policy research and practice in STIG systems. Res. Policy 38, 681–693.
Amable, B., 2000. Institutional complementarity and diversity of social systems of innovation and production. Rev. Int. Polit. Econ. 7 (4), 645–687.
Amorós, J.E., Bosma, B., 2013. Fifteen years of assessing entrepreneurship across the globe. Global Entrepreneurship Monitor (GEM). Babson College, Babson Park, MA.
Audretsch, D.B., Feldman, M.P., 1996. R&D spillovers and the geography of innovation and production. Am. Econ. Rev. 86, 630–640.
Audretsch, D.B., Seitz, N., Rouch, K.M., 2018. Tolerance and innovation: the role of institutional and social trust. Eurasian Bus. Rev. 8 (1), 71–92.
Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17 (1), 99–120.
Bathelt, H., Malmberg, A., Maskell, P., 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Prog. Hum. Geogr. 28 (1), 31–56.
Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Res. Policy 37 (3), 407–429.
Beuse, M., Schmidt, T.S., Wood, V., 2018. A "technology-smart" battery policy strategy for Europe. Science 361 (6407), 1075–1077.
Binz, C., Truffer, B., 2017. Global innovation systems—a conceptual framework for innovation dynamics in transnational contexts. Res. Policy 46 (7), 1284–1298.
Bohn, R.E., 1994. Measuring and managing technological knowledge. Sloan Manag. Rev. 36 (1), 61–73.
Breschi, S., Malerba, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In: Edquist, Charles (Ed.), Systems of Innovation: Technologies, Institutions and Organizations. Routledge, London, pp. 130–156.
Brockman, P, Khurana, I.K., Zhong, R., 2018. Societal trust and open innovation. Res. Pol. 47 (10), 2048–2065.
Carayannis, E., 2000. Strategic Management of Technological Learning, 1st ed. Taylor & Francis, Boca Raton.
Carlsson, B., Jacobsson, S., 1997. In search of useful public policies—key lessons and issues for policy makers. In: Technological Systems and Industrial Dynamics. Springer, Boston, MA, pp. 299–315.
Carson, S.J., Madhok, A., Wu, T., 2006. Uncertainty, opportunism, and governance: the effects of volatility and ambiguity on formal and relational contracting. Acad. Manag. J. 49 (5), 1058–1077.
Chesbrough, H.W., 2003. Open Innovation: The New Imperative for Creating and Profiting From Technology. Harvard Business Press, Boston.
Cirillo, V., Martinelli, A., Nuvolari, A., Tranchero, M., 2019. Only one way to skin a cat? Heterogeneity and equifinality in European national innovation systems. Res. Policy 48 (4), 905–922.
Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. Lawrence Erlbaum, Hillside, NJ.
Conner, K.R., Prahalad, C.K., 1996. A resource-based theory of the firm: knowledge versus opportunism. Organ. Sci. 7 (5), 477–501.
Cooke, P., 2001. Regional innovation systems, clusters, and the knowledge economy. Ind. Corporate Change 10 (4), 945.
Dahlander, L., 2007. Penguin in a new suit: a tale of how de novo entrants emerged to harness free and open source software communities. Ind. Corp. Chang. 16 (5), 913–943.
Dahlander, L., Gann, D.M., 2010. How open is innovation? Res. Policy 39 (6), 699–709.
Dewald, U., Fromhold-Eisebith, M., 2015. Trajectories of sustainability transitions in scale-transcending innovation systems: the case of photovoltaics. Environ. Innov. Soc. Transit. 17, 110–125.
Dodgson, M., 1991. The Management of Technological Learning: Lessons From a Biotechnology Company. Walter de Gruyter, Berlin.
Edquist, C., Lundvall, B.A., 1993. Comparing the Danish and Swedish Systems of Innovation. In: Nelson, R. (Ed.), National Innovation Systems: A Comparative Analysis. Oxford University Press, Oxford, pp. 265–298.
Ernst, D., 1998. Catching-up, crisis, and industrial upgrading: evolutionary aspects of technological learning in Korea's electronics industry. Asia Pac. J. Manag. 15 (2), 247–283.
Felin, T., Zenger, T.R., 2014. Closed or open innovation? Problem solving and the governance choice. Res. Policy 43 (5), 914–925.
Fornell, C., Cha, J., 1994. Partial Least Squares. Adv. Methods Market. Res. 407, 52–78.
Freeman, C., 1987. Technology Policy and Economic Performance: Lessons From Japan. Frances Pinter, London.
Freeman, C., Clark, J., Soete, L., 1982. Unemployment and Technical Innovation: A Study of Long Waves and Economic Development. Burns & Oates, London.
Garud, R., Jain, S., Kumaraswamy, A., 2002. Institutional entrepreneurship in the sponsorship of common technological standards: the case of Sun Microsystems and Java. Acad. Manag. J. 45 (2002), 196–214.
Ghazinoory, S., Daneshmand-Mehr, M., Arasti, M.R., 2014. Developing a model for integrating decisions in technology roadmapping by fuzzy PROMETHEE. J. Intell. Fuzzy Syst. 26 (2), 625–645.
Ghazinoory, S., Bitaab, A., Lohrasbi, A., 2014. Social capital and national innovation system: across-country analysis. Cross Cult. Manag. 21 (4), 453–475.
Graf, H., Kalthaus, M., 2018. International research networks: determinants of country embeddedness. Res. Policy 47 (7), 1198–1214.
Granstrand, O., Holgersson, M., 2020. Innovation ecosystems: a conceptual review and a new definition. Technovation 90, 102098.
Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strateg. Manag. J. 17, 109–122.
Grau, T., Huo, M., Neuhoff, K., 2012. Survey of photovoltaic industry and policy in Germany and China. Energy Policy 51, 20–37.
Greenstein, S., Nagle, F., 2014. Digital dark matter and the economic contribution of Apache. Res. Policy 43 (4), 623–631.
Hair, J.F., Ringle, C.M., Sarstedt, M., 2011. PLS-SEM: indeed a silver bullet. J. Mark. Theory Pract. 19 (2), 139–152.
Hair Jr., J.F., Sarstedt, M., Hopkins, L., Kuppelwieser, V.G., 2014. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. Eur. Bus. Rev. 26 (2), 106–121.
Hekkert, M.P., Suurs, R.A., Negro, S.O., Kuhlmann, S., Smits, R.E., 2007. Functions of innovation systems: a new approach for analysing technological change. Technol. Forecast. Soc. Chang. 74 (4), 413–432.
Hipp, A., Binz, C., 2020. Firm survival in complex value chains and global innovation systems: evidence from solar photovoltaics. Res. Policy 49 (1), 103876.
Hitt, M.A., Ireland, R.D., Lee, H.-U., 2000. Technological learning, knowledge management, firm growth and performance: an introductory essay. J. Eng. Technol. Manag. 17 (3–4), 231–246.
Hoang, H, Rothaermel, F.T., 2005. The effect of general and partner-specific alliance experience on joint R&D project performance. Acad. Manag. J. 48 (2), 332–345.
Hobday, M., 1994. Technological learning in Singapore: a test case of leapfrogging. J. Dev. Stud. 30 (4), 831–858.
Hoppmann, J., 2018. The role of interfirm knowledge spillovers for innovation in massproduced environmental technologies: evidence from the solar photovoltaic industry. Organ. Environ. 31 (1), 3–24.
Jacobsson, S., Bergek, A., 2011. Innovation system analyses and sustainability transitions: contributions and suggestions for research. Environ. Innov. Soc. Transit. 1 (1), 41–57.
Kaplan, S., Murray, F., 2010. Entrepreneurship and the construction of value in biotechnology. In: Technology and Organization: Essays in Honour of Joan Woodward. Emerald Group Publ. ltd., Bingley.
Kazanjian, R.K., Drazin, R., Glynn, M.A., 2000. Creativity and technological learning: the roles of organization architecture and crisis in large-scale projects. J. Eng. Technol. Manag. 17, 273–298.
Kim, L., 1997. Imitation to Innovation: The Dynamics of Korea's Technological Learning. Harvard Business School Press, Boston, MA.
Lakhani, K.R., Lonstein, E., 2011. InnoCentive.com (B). Harvard Business School General Management Unit Case (612-026).
Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. Strateg. Manag. J. 27 (2), 131–150.
Lee, K., Malerba, F., 2017. Catch-up cycles and changes in industrial leadership: windows of opportunity and responses of firms and countries in the evolution of sectoral systems. Res. Policy 46 (2), 338–351.
Lichtenthaler, U., Lichtenthaler, E., 2009. A capability-based framework for open innovation: complementing absorptive capacity. J. Manag. Stud. 46 (8), 1315–1338.
Lorenzoni, G., Lipparini, A., 1999. The leveraging of interfirm relationships as a distinctive organizational capability: a longitudinal study. Strateg. Manag. J. 20 (4), 317–338.
Lundvall, B.-A., 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter Publishers, London.
Lundvall, B.-A., 2015. The origins of the national innovation system concept and its usefulness in the era of the globalizing economy. In: 13th Globelics Conference, pp. 23–26. Havana, Cuba.
Maguire, S., McKelvey, B., Mirabeau, L., Ötzas, N., 2006. Complexity science and organization studies. The SAGE Handbook of Organization Studies, 2nd ed. Sage, London, pp. 165–214.
Mahmood, T., Mubarik, M.S., 2020. Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity. Tech. For. Soc. Chang. 160 (120248), 1–9.
Malerba, F., 2002. Sectoral systems of innovation and production. Res. Policy 31 (2), 247–264.
Malerba, F., 2005. Sectoral systems of innovation: a framework for linking innovation to the knowledge base, structure and dynamics of sectors. Econ. Innov. N. Technol. 14 (1–2), 63–82.

Malerba, F., Nelson, R., 2011. Learning and catching up in different sectoral systems: evidence from six industries. Ind. Corp. Change 20 (6), 1645–1675.
Malmberg, A., Maskell, P., 2002. The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering. Environ. Plan. A 34 (3), 429–449.
Mubarik, M.S., et al., 2021. Intellectual capital and supply chain resilience. J. Intellect. Cap. 23 (3), 713–738.
Musiolik, J., Markard, J., 2011. Creating and shaping innovation systems: formal networks in the innovation system for stationary fuel cells in Germany. Energy Policy 39, 1909–1922.
Musiolik, J., Markard, J., Hekkert, M., 2012. Networks and network resources in technological innovation systems: towards a conceptual framework for system building. Tech. For. Soc. Chang. 79 (6), 1032–1048.
Musiolik, J., Markard, J., Hekkert, M., Furrer, B., 2020. Creating innovation systems: how resource constellations affect the strategies of system builders. Technol. Forecast. Soc. Chang. 153, 119209.
Nelson, R., Rosenberg, N., 1993. Technical innovation and national systems. In: Nelson, R. (Ed.), National Innovation Systems: A Comparative Analysis. Oxford University Press, New York, pp. 1–18.
Nieto, M.J., Rodríguez, A., 2011. Offshoring of R&D: looking abroad to improve innovation performance. J. Int. Bus. Stud. 42 (3), 345–361.
OECD, 2008. The Internationalisation of Business R & D: Evidence, Impacts and Implications. Organisation for Economic Co-operation and Development.
Ozman, M., 2009. Inter-firm networks and innovation: a survey of literature. Econ. Innov. New Technol. 18 (1), 39–67.
Pan, X., Song, M.L., Zhang, J., Zhou, G., 2018. Innovation network, technological learning and innovation performance of high-tech cluster enterprises. J. Knowl. Manag. 23 (9), 1729–1746.
Parmigiani, A., Rivera-Santos, M., 2011. Clearing a path through the forest: a meta-review of interorganizational relationships. J. Manag. 37 (4), 1108–1136.
Pietrobelli, C., Rabellotti, R., 2009. The global dimension of innovation systems: linking innovation systems and global value chains. In: Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting. Edward Elgar, Cheltenham, pp. 214–238.
Podmetina, D., Soderquist, K.E., Petraite, M., Teplov, R., 2018. Developing a competency model for open innovation: From the individual to the organisational level. Manag. Dec. 56 (6), 1306–1335.
Radosevic, S., 2022. Techno-economic transformation in Eastern Europe and the former Soviet Union–a neo-Schumpeterian perspective. Res. Policy 51 (1), 104397.
Radosevic, S., Yoruk, E., 2012. SAPPHO revisited: factors of innovation success in knowledge-intensive enterprises in Central and Eastern Europe. In: Druid 2012. Druid Society, pp. 1–24.
Radosevic, S., Yoruk, D.E., Yoruk, E., 2019. Technology upgrading and growth in Central and Eastern Europe. In: Social and Economic Development in Central and Eastern Europe: Stability and Change After 1990, 1st ed. Routledge, London, pp. 178–204.
Radziwon, A., Bogers, M., 2019. Open innovation in SMEs: Exploring inter-organizational relationships in an ecosystem. Tech. For. Soc. Chang. 146, 573–587.
Rakas, M., Hain, D.S., 2019. The state of innovation system research: what happens beneath the surface? Res. Policy 48 (9), 103787.
Rothwell, R., 1994. Towards the Fifth-generation Innovation Process. Int. Market. Rev. 11 (1), 7–32.
Sanchez, G., 2013. PLS path modeling with R. Trowchez Editions, Berkeley.
Sanchez, R., Heene, A., 1997. Reinventing strategic management: new theory and practice for competence-based competition. Eur. Manag. J. 15 (3), 303–317.
Shaikh, M., Levina, N., 2019. Selecting an open innovation community as an alliance partner: looking for healthy communities and ecosystems. Res. Policy 48 (8), 103766.
Shmueli, G., Sarstedt, M., Hair, J.F., Cheah, J.H., Ting, H., Vaithilingam, S., Ringle, C.M., 2019. Predictive model assessment in PLS-SEM: guidelines for using PLSpredict. Europ. J. Mark. 53 (11), 2322–2347.
Simpson, B.M., Seidel, R., Byrne, S., Woods, C., Crossan, M.M., Olivera, F., 2001. Technological Learning: Towards an Integrated Model. Organizational Learning & Knowledge Management: New Directions. Uni. Western Ontario, Ontario.
Stephan, A., Schmidt, T.S., Bening, C.R., Hoffmann, V.H., 2017. The sectoral configuration of technological innovation systems: patterns of knowledge development and diffusion in the lithium-ion battery technology in Japan. Res. Policy 46 (4), 709–723.
Szapiro, M., Vargas, M.A., Brito, M.M., Cassiolato, J.E., 2016. Global Value Chains and National Systems of Innovation: Policy Implications for Developing Countries. UFRJ, Rio de Janeiro.
Teirlinck, P., Spithoven, A., 2013. Research collaboration and R&D outsourcing: different R&D personnel requirements in SMEs. Technovation 33 (4–5), 142–153.
Tojeiro-Rivero, D., Moreno, R., 2019. Technological cooperation, R&D outsourcing, and innovation performance at the firm level: the role of the regional context. Res. Policy 48 (7), 1798–1808.
Vanhaverbeke, W., Van de Vrande, V., Chesbrough, H., 2008. Understanding the advantages of open innovation practices in corporate venturing in terms of real options. Creat. Innov. Manag. 17 (4), 251–258.
Von Hippel, E., 2005. Open source software projects as user innovation networks. In: Lessig, L., Shirky, C., Cusumano, M. (Eds.), Perspectives on Free and Open Source Software. MIT Press, Cambridge, pp. 267–278.
Wan, Y., Gao, Y., Hu, Y., 2022. Blockchain application and collaborative innovation in the manufacturing industry: Based on the perspective of social trust. Tech. For. Soc. Chang. 177, 1–10.
Wang, Y., Vanhaverbeke, W., Roijakkers, N., 2012. Exploring the impact of open innovation on national systems of innovation—A theoretical analysis. Tech. For. Soc. Chang. 79 (3), 419–428.
WEF (2022). The World Economic Forum. Retrieved 30 July 2022, from https://www.weforum.org/.
WB (2022). The World Bank. Retrieved 30 July 2022, from https://www.worldbank.org/en/home.
Whitley, R., 2000. The institutional structuring of innovation strategies: business systems, firm types and patterns of technical change in different market economies. Organ. Stud. 21 (5), 855–886.
Zahra, S.A., Ireland, R.D., Hitt, M.A., 2000. International expansion by new venture firms: international diversity, mode of market entry, technological learning, and performance. Acad. Manag. J. 43 (5), 925–950.

Monika Petraite is a Full Professor and Principal Investigator of the Innovation and Entrepreneurship Research Group at School of Economics and Business, Kaunas University of Technology, Lithuania. She is also the Director of Global R&D Research Centre of Central Eastern Europe and leads the Open Innovation Research cluster focusing Open Innovation Ecosystems, Internationalization and digitization of Innovation and entrepreneurship, and other related areas. In addition, she is a founding member of the International Association of Knowledge Management, member of ISPIM, RADMA and the Knowledge-Economy Forum Lithuania. She acts as an innovation policy expert at the EU and national level. In addition, she promotes innovation and entrepreneurship leadership across women and youth via public speaking, TEDx talks, and mentoring activities.

Muhammad F. Mubarak is a Ph.D. research fellow at the School of Economics and Business, Kaunas University of Technology, Lithuania. He is also visiting PhD scholar and trainee at University College London, United Kingdom and Copenhagen Business School, Denmark, and a Research Associate with GLORAD-CEE. In addition, he is working on several European Union funded projects. His research interests are technological learning and upgrading of CEE, intellectual capital, collaborative innovation networks, industry 4.0/5.0, and sustainable innovations. He has presented his research at various international conferences including ISPIM and RADMA, and published in journals such as TFSC, SPC and IJEM.

Rimantas Rauleckas is an Associate Professor and a member of Public Governance Research group at the Faculty of Social Sciences, Humanities and Arts, Kaunas University of Technology, Lithuania. His research interests are social science methodology, innovation, and public policy analysis. He has published on digitalization, product innovation, public policy, and strategic agility in high-level journals. He is also an expert in quantitative data analysis techniques including SMART PLS. He has served as an expert at Lithuanian data archive for social sciences and humanities at KTU. He acted as Project Manager and Interim Executive Director at Kaunas Municipal Training Center. Mr. Rimantas has worked and supervised several EU funded research projects on public policy reforms and governance.

Max von Zedtwitz is a Professor of Global Innovation at Copenhagen Business School (CBS), with adjunct roles at KTU in Lithuania and at SDU in Denmark. He is the Founding Director of GLORAD, a research network for global R&D and innovation research with centers in St. Gallen, Shanghai, Kaunas, Sao Paulo, Silicon Valley, and Copenhagen. Previsouly, he was a professor at IMD in Lausanne (2000), Tsinghua University in Beijing (2003), and Skoltech in Moscow (2013). He has written >100 scientific articles and 17 books; he also is an Area Editor with Technovation. He holds Ph.D. and MBA degrees from the University of St. Gallen, and a M.Sc. in Computer Science from ETH Zurich.