DOCTORAL THESIS

Institutions and Innovativeness of SMEs

Helery Tasane

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for doctoral or equivalent academic degree.

Helery Tasane

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Institutsioonid ning väikeste ja keskmise suurusega ettevõtete innovatsioonivõimekus

HELERY TASANE

TAL TECH
KIRJASTUS

Contents

List of publications

The author's publications that form the basis of this thesis are as follows:

I Tasane, H., & Srun, S. (2023). The Institutional Environment, Human Capital Development, and Productivity-Enhancing Factors: Evidence from ASEAN Countries. *TRaNS: Trans-Regional and-National Studies of Southeast Asia*, 1–16. DOI: https://doi.org/10.1017/trn.2022.13 (ETIS 1.1)

II Tasane, H., Ashyrov, G., & Srun, S. (2023). Institutions and R&D engagement of SMEs in Laos. *Post-Communist Economies*, 35(4), 384–402. DOI: https://doi.org/10.1080/14631377.2023.2188687 (ETIS 1.1)

III Ashyrov, G; Tasane, S. (2023). The roles of foreign and domestic ownership in the corruption–firm innovation nexus. *Bulletin of Economic Research*, 1–36. DOI: http://doi.org/10.1111/boer.12419 (ETIS 1.1)

IV Ferraro, S., Männasoo, K., & Tasane, H. (2023). How the EU Cohesion Policy targeted at R&D and innovation impacts the productivity, employment and exports of SMEs in Estonia. *Evaluation and Program Planning*, 97, 102221. DOI: https://doi.org/10.1016/j.evalprogplan.2022.102221 (ETIS 1.1)

Author's Contributions to the Publications

The author's contributions to the papers used in this thesis were as follows:

I As lead author of the paper, they were responsible for setting the hypothesis, carrying out the literature review, preparing the dataset, carrying out the quantitative analysis and drawing the study's conclusions. The Co-author of the paper provided an intuitive understanding of the cultural, institutional, and economic background of the countries involved in the study.

II As the lead author of the paper, they set the hypothesis, carried out most of the literature review, prepared the dataset, carried out the quantitative analysis and drew most of the conclusions. Co-author Gaygysyz Ashyrov supported the paper's development with a literature review concerning the bribery and innovation nexus and by interpreting the results for the conclusions. Co-author Sopheak Srun was responsible for the intuitive interpretation of Laos's institutional background.

III The author of this thesis was responsible for data collection, methodological design, carrying out the empirical investigation and interpreting the results.

IV The author of this thesis supported the study by preparing the dataset, carrying out the econometric evaluation and presenting the results.

Introduction

Technological advances in the past few hundred years have altered economic growth and development and have done so faster than ever before (Galor, 2005). This economic development has, however, been unequal across nations, motivating the researchers to understand the drivers of economic growth and development along with underlying reasons for the differences in wealth distribution across countries (see, for example, Romer, 1986 and 1990; Lucas, 1990; Rivera-Batiz and Romer, 1991; Aghion and Howitt, 1992; Abramovitz, 1993; Hall and Jones, 1999; Funke and Strulik, 2000; Barro, 2001; Hibbs and Olsson, 2004; Bilbao-Osorio and Rodríguez-Pose, 2004; Galor and Moav, 2004; Alfaro et al., 2008; Ali et al., 2018; Thompson, 2018; and many others). Yet the question remains: why have some nations witnessed faster economic growth and development than others?

Following Acemoglu et al. (2014) and North and Thomas (1973), the countries that witnessed higher economic growth were characterised by higher levels of total factor productivity, were more innovative, and had a greater resource pool of educated workers and physical capital through machines, tools, and factories. Innovation, physical capital, and human capital correspond to the production factors in aggregate production function. These production factors, however, do not explain why some countries have managed to accumulate more of these production factors than others.

North and Thomas (1973) argued that, broadly speaking, there are two determinants for economic growth: fundamental factors and proximate factors. The proximate factors include the above-mentioned production factors, like physical capital, knowledge stock and innovation, which are present in the aggregate production function. As the proximate factors refer to production factors, they reflect the tangible and intangible sources of prosperity. The fundamental factors include institutional settings that determine the structures of interaction in the society. These societal structures of interactions provide the framework in which the economic agents operate, determining different constraints on and enablers of individual actions and leading to the accumulation of proximate factors. The challenge in understanding the causal mechanisms between economic development and institutional development is the endogeneity of their operation, as institutional framework changes in tandem with economic development (Acemoglu et al., 2014).

The early definition of institutions provided by North in his 1993 work was that institutions are sets of rules, regulations, and procedures along with moral and ethical norms that constrain individual action and behaviour. This definition captures both formal and informal institutions. The formal institutions in this definition include codified rules, regulations, and procedures, which facilitate transactions between agents to reduce uncertainty. They are usually politically determined and enforced from the top down. Informal institutions, on the other hand, are unwritten norms and customs that are inherited through culture, traditions, and social networks. (North, 1991; North, 1993; Greif, 2006).

Avner Greif's (2006) work exploring the role of institutions placed more emphasis on the informal institutions (like historical background, cultural norms, and social capital) as shapers of individual behaviour and decision-making. Greif (2006) underscored that informal institutions shape the formation of formal institutions and points out that the formal institutions' efficiency depends on how they interact with sociocultural factors. Williamson's (2000) approach to institutions was to explore the roles of formal institutions

(rules and regulations) and informal institutions (customs and traditions) as a set of structures to mitigate transaction costs, reduce uncertainty and shape individual interactions. Hodgson's (2006) work on the role of institutions built on Greif's (2006) point of view by explaining the role of social and historical context in the formation of social structures, where institutions are systems of established and embedded rules that form through agents' actions and guide further social interaction between individuals. Hodgson's (2006) definition of institutions included firms and organisations as special institutions, which have clear criteria and boundaries to distinguish members and non-members, have sovereignty in power structures, and set line of commands given the structure enforced on the members of the special institution. Baland, Bourguignon, Platteau and Verdier (2020) relied on North's earlier work for their definition of institutions and state that institutions are rules, procedures or other human constraints that restrict individual action and thus enable the coordination of individual actions in society.

These definitions lay the groundwork for understanding how different social interactions shape individual behaviour, but they provide little guidance on empirical estimation strategy, as the meaningful separation of some forms of institutions (e.g., culture) from other institutions is often difficult. This has led to the main distinction of formal and informal institutions in empirical studies as legal institutions are different and are more easily observable in empirical settings (Durlauf, 2020).

Nevertheless, institutions provide structure governing social and economic interactions that subsequently alter economic outcomes. Since the business sector is one of the most important sources of economic growth, wherein small and medium-sized enterprises (SMEs) play a pivotal role in the economy through job creation, product diversification and promoting competition in the market (Ayyagari et al., 2007), this thesis further investigates the role of formal and informal institutions on SMEs'[1] productivity and the growth-enhancing pursuits of research and development, and innovation (R&DI). In so doing, this thesis provides useful insight into how formal institutions (e.g., political stability or uncertainty, voice and accountability, property rights, and government R&DI policy) and informal institutions (e.g., corruption) associate with SMEs' R&DI engagement and subsequent productivity, employment and exporting outcomes, which are indispensable for achieving sustainable long-term economic development (Shefer and Frenkel, 1998; Hall and Reenen, 2000; Frenkel et al., 2001; Tambunan, 2008).

The thesis consists of four published articles. The first article, entitled "The Institutional Environment, Human Capital Development, and Productivity-Enhancing Factors: Evidence from ASEAN Countries" explores the association between the fundamental determinants of economic growth and proximate factors. It does so by examining institutional settings among nine Association of Southeast Asian Nations (ASEAN) countries. in this way, the article provides context in understanding how institutional settings are associated with factors of wealth generation and economic growth. The novelty of this study stems from its comparative analysis and regional focus, which enable the author to uncover institutional differences and determine how regulatory aspects interact with human capital accumulation in ways relevant for value creation and productivity growth across the countries included in the study, which are characterised by high heterogeneity in economic development.

[1] SME sector makes up an average of 90% of all businesses worldwide and contributes more than 50% of all employment. More information available at: https://www.worldbank.org/en/topic/smefinance#:~:text=SMEs%20account%20for%20the%20majority,(GDP)%20in%20emerging%20economies.

The second article, entitled "Institutions and R&D engagement of SMEs in Laos" explores SMEs' R&D engagement in the single-party communist state of the Lao People's Democratic Republic. This study explores the association between R&D engagement, the perception of formal institutions and the prevalence of informal institutions, like corruption, among SMEs operating in an economy possessing low overall economic development and high institutional inefficiency. The novelty of this study stems from its national context, which enables the author to distinguish the derived results from the rest of the studies focusing on exploring the drivers of R&D engagement. Thus, this study provides useful insight into the political and social contexts governing how different institutions interact with SMEs' R&D engagement, suggesting practical implications about institutional barriers to strengthening strategies promoting knowledge-intensive development through R&D-based value-enhancing pursuits among SMEs.

The third paper, entitled "The roles of foreign and domestic ownership in the corruption–firm innovation nexus" investigates bribe solicitation and innovation engagement among SMEs operating in developing economies. This paper develops insights into whether corruption, as an institutional dysfunctionality, is differently associated with innovation in the context of foreign owned versus domestically owned firms that operate in economies possessing low overall research and development (R&D) and engage in exporting. The study underscores the importance of institutional and policy solutions to coordination failures. The paper's novelty stems from the context of prevalent informal institutional settings within the nexus of firm ownership, which is still little explored in the broader context of developing economies with diverse historical and cultural backgrounds.

The fourth paper, "How the EU Cohesion Policy targeted at R&D and innovation impacts the productivity, employment and exports of SMEs in Estonia", investigates the effects of government support on research, development and innovation on firm-level productivity growth, employment outcomes and exporting. This study assesses whether Cohesion Funds' R&D and innovation policy grants are effective and lead to positive short-term outcomes in firm performance. This study provides novel insights in the context of Estonia, a small EU member country with high per capita levels of EU-funded support.

The broader contribution of this thesis research is that it deepens the existing knowledge about the association of productivity-enchasing factors in varying institutional contexts, exploring the barriers presented by formal and informal institutions to knowledge-intensive growth, and the effectiveness of government strategies promoting entrepreneurial outcomes through policy interventions. The structure of the thesis is as follows. Section one provides an overview of the background literature. Section two describes the thesis' research questions and hypotheses. Section three provides a methodological overview of the thesis. Section four builds upon the discussion of the findings and the conclusions of the component papers.

1 Background literature

Institutions are one of the key elements for understanding the differences in economic development between nations (Acemoglu et al., 2001). They set the formal and informal rules, norms and practices for individual reasoning and decision-making. Institutions provide a framework for the collective coordination and interaction of economic agents (North, 1993; Greif, 2006; Williamson, 2000; Acemoglu et al., 2001; Hodgson, 2006 among others).

Empirical evidence gathered by Acemoglu et al. (2001) has shown that institutional differences describe most of the variation in the outcomes of countries' economic performance. In their work, Acemoglu et al. (2001) explored the linkages between the difference in mortality rates and colonisation strategies that Europeans adopted, making a significant methodological contribution by measuring the quality of institutions. Based on their findings, the authors argued that the colonial strategies that emphasised the inclusivity of private property protections and checks against government power misuse persisted even after colonisation, and paved the way for subsequent institutional development and better economic performance compared to extractive states, due to the improved conditions for investments in physical and human capital.

Robert J. Barro's research (1990, 1996, 1999) is dedicated mostly to the role of property rights; he found that the enforcement of those rights is crucial for the investment activity of economic agents. Increased uncertainty about property rights and the legal system tends to decrease entrepreneurial incentives in the economy, increase saving rates instead of promoting investments, and consequently hinder productivity gains. Hence, in order to enforce property rights, states' involvement through formal institutions is inevitable (Hodgson, 2006), but it does not always efficiently provide equal rights for all parties. For example, Djankov et al.'s (2003) work was dedicated to analysing the court system and resolution of legal disputes among 109 countries of different development levels. Their findings underscored that less developed economies usually lacked well-designed legal systems. Rather, the legal systems in such countries were characterised by the misuse of power, prevalence of corruption, biased outcomes in legal disputes and a low level of overall trust in the legal system. These less developed countries failed to overcome coordination failures and thus hindered productivity growth and economic development. The work of La Porta et al. (1997) extends this view by providing additional perspectives on the performance of capital markets, concluding that an inefficient legal system deters investment activities and results in smaller and narrower capital markets.

Low willingness to engage in economic activities due to the inefficiency of formal institutions to solve coordination failures also hinders the adoption of new technologies and reduces incentives to innovate due to the higher uncertainty, deepening credit constraints and the appropriability problems of returns (Hall and Jones, 1999; Coe et al., 2009; Brown et al. 2017). These investments, however, are considered essential for achieving sustainable long-run growth through value creation (Shefer and Frenkel 1998; Hall and Reenen 2000; Frenkel et al. 2001; Bello et al., 2004).

What constitute the reasons for the differences in institutional development? One aspect could be the accumulation of human capital. Lipset (1959) and Glaeser et al. (2004) suggest that the accumulation of human capital promotes the strengthening of institutions, which leads to subsequent economic development. The fundamental idea behind this view is that in order for a legal system to operate effectively, it requires

sufficient human capital capable of running the systems and solving problems through negotiation (see Djankov et al., 2003; Glaeser et al., 2004).

North and Thomas (1973), on the other hand, considered institutional development to be an enabler for the proximate factors, which include human capital accumulation, that achieve economic growth and development. This view is also supported by Acemoglu et al. (2001), who showed that physical capital and human capital accumulation promotes economic growth and subsequent economic development among countries with sufficient institutional settings. Similarly, Acemoglu and Robinson (2012), Dias and Tebaldi (2012), and Ali et al. (2018) concluded that institutional development enables higher utility to be derived from human capital.

Another aspect of institutional development is the complexity of social development and the interaction of formal and informal institutions. Although empirical evidence on the contributions of formal institutions to economic growth and development exists, the results of its analysis are often tenative, leading to the role of informal institutions like networks, culture, history, values, norms and more, affecting both the effectivness and development of formal institutions (Djankov et al., 2003; Greif, 2006; North et al., 2009).

1.1 Entrepreneurship, value creation and institutions

Entrepreneurship is the main driver for generating economic wealth through job creation and product diversification, which lead to subsequent competition in the market. The pressure of competition, in turn, favours more efficient allocation and use of resources and promotes technological change and innovation (Moran and Ghoshal, 1999; Acs, 2006; Acemoglu and Robinson, 2012). Investments in research and development (R&D) are considered an indispensable prerequisite for innovating and for achieving sustainable growth through value creation (Shefer and Frenkel, 1998; Hall and Reenen, 2000; Frenkel et al., 2001).

Value creation is the process of combining resources expressed as products. Various combinations of resources can manifest in products with different values (Moran and Ghoshal, 1999). Product differentiation enables firms to increase product varieties, and thus generate higher growth. However, based on fundamental historical data, in such a differentiation, product identity and differentiation strategies matter. Braguinsky et al. (2021) indicated that firms that are characterised by high long-term growth expand their technological frontiers and experiment with new, innovative products that are later expanded horizontally. Experimenting with vertical value creation in product differentiation requires firms to overcome supply-side constraints by adopting new technologies and increasing knowledge through human capital. Overcoming these constraints proved to have significant spillover effects as the new technologies and knowledge were broadly applicable for horizontal differentiation as well.

The institutional setting constitutes the framework in which the firms operate. An inclusive institutional setting with emphasis on property rights, contract enforcement and access to financing or venture capital is crucial for encouraging competition through entrepreneurial incentives. The allocation of resources, adoption of new technologies and undertaking R&DI and trade subsequently enables firms to derive higher utility per worker (Hall and Jones, 1999; Maskus, 2000; Rodrik et al., 2004; Acemoglu and Robinson, 2012). These linkages between institutions, production factors and subsequent productivity outcomes can be illustrated in the very simple diagram given in Figure 1, below, which follows from the works of North and Thomas (1973) and Hall and Jones (1999).

Figure 1. Linkages between institutions, production factors and output per worker. Source: Author's creation based on Hall and Jones (1999).

Hall and Jones (1999), like Acemoglu et al. (2014), argued that in a weak institutional setting, which they described in terms of high corruption, weak contract enforcement and ineffectual legal systems, government interference leads to higher uncertainty and reduced incentives to engage in economic activities. Thus, resources and capital that would otherwise be allocated to production, technology adoption and innovation will instead be used for protecting against diversion. This also hinders subsequent human capital accumulation from knowledge-intensive activities. On the micro-level, these linkages can be described following Bjørnskov and Foss (2016), as shown in Figure 2 below.

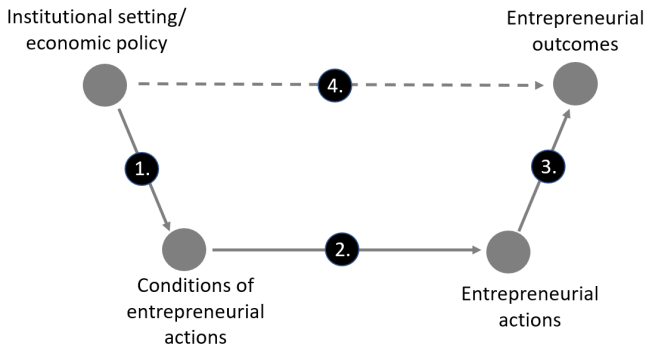

Figure 2. Connections between institutional environment and entrepreneurial actions and outcomes. Source: Author's creation based on Bjørnskov and Foss's (2016) interpretation of Coleman (1990).

The connections in Figure 2 illustrate the simplified micro- and macro-level structures of the causal relationship between how the macro-level institutional environment, entrepreneurial actions, and subsequent aggregate outcomes through entrepreneurial decisions are connected. It uses the Coleman diagram, which is a sociological model that serves as a cognitive tool to structure how large-scale social phenomena can be linked with small-scale events or processes in a very simplified manner (Ylikoski, 2021). Following Bjørnskov and Foss (2016), the first arrow of the matrix shows the how macro-level institutions and economic policies (shown in the upper-left corner), which contain enablers and constraints for the business sector, mediate the conditions for the business sector (micro-level) shown in the lower-left corner. This in turn shapes the entrepreneurial decisions (micro-level) shown in the lower-right corner, which include decisions about business creation and engaging in activities that may embed in the macro-level productivity outcomes shown in the upper-right corner (Bjørnskov and Foss, 2016).

The entrepreneurial responses to the economic policies and the overall institutional setting are, however, heterogeneous. For example, Greenwood et al. (2010) showed that heterogeneity in the response to the complex institutional context may be derived from different nonmarket factors, like firms' size, regional conditions, or, in case of very small or family-owned firms, family logics. McMullen and Sheperd (2006) addressed the roles of entrepreneurial knowledge, motivation, and strategy in the pursuit of different opportunities. Rodgers et al. (2022) found that SMEs in particular use nonmarket strategies to operate in and beyond some given market settings. In addition, DiMaggio (1988), Maguire et al. (2004), Garud et al. (2007), and Pacheco et al. (2010), among others, argued that entrepreneurial activities may lead to a change in the institutional environment, referring to the potential endogeneity in the system of macro-level enablers of and constraints on micro-level responses (Bjørnskov and Foss, 2016).

Following the Coleman diagram framework provided by Bjørnskov and Foss (2016), the first article of this study explores the macro-level institutional setting by addressing the human capital and institutional strength that create conditions of entrepreneurial action, leading to entrepreneurial outcomes of productivity. The second and third papers of this thesis explore the self-perceived micro-level conditions for entrepreneurial actions and the decision to engage in R&DI. The final paper of this study addresses the entrepreneurial outcomes of the decision to engage in R&DI stimulated by the macro-level policy targeting industrial R&DI.

1.2 Corruption and entrepreneurial incentives to engage in R&DI

Protection of intellectual property rights promotes R&DI and subsequent innovation by granting investors exclusive legal rights over inventions. The property rights system failing results in increased risks on returns to R&DI, creates an unfavourable environment for investment decisions by having adverse effects on profit reinvestment decisions, and decreases the willingness of potential participants to undertake such investments (Rugman, 1986; Johnson et al., 2002; Cull and Xu, 2005; Coe et al., 2009; Hall et al., 2010). As a result, a weak institutional environment may lead to a situation where political connections are used to enhance operations, improve access to finance, and safeguard property rights or litigation risks (Boubakri et al., 2013; Cumming et al., 2016; Xu et al., 2016). In such settings, bribery emerges as a way of doing business (Ashyrov, 2020) that hedges against political risks and overcomes bureaucratic rigidities (Krammer, 2019).

There exist two distinct views on the effects of corruption on firm R&DI. The first, supported by the results of studies by De Waldemar (2012) and Paunov (2016), among others, considers corruption as deteriorative by creating costs and uncertainty for the firms and thus acting to 'sand the wheel' by hindering R&DI. Regardless of increased costs, extortion risk, and uncertainty accompanied by corruption (e.g., De Waldemar, 2012; Paunov, 2016; Huang and Yuan, 2021), entrepreneurs might accept the short-term transactional benefits of corruption over the burdensome procedures in business environments where the institutional setting is poor. However, in the long term, firms may find it difficult to cope with the costs of corruption, which leads to damage to the competitive marketplace (Huang & Yuan, 2021) and hampers international trade (De Jong and Bogmans, 2011) and innovation (Paunov, 2016).

Another strand of studies, however, has found corruption to be a 'grease the wheel' mechanism compensating for inefficient bureaucratic systems (Méon and Weill, 2010; Nguyen et al., 2016; Xie et al., 2019). This idea underlies the theory that bribes may function as a supplementary income to government officials' low wages, resulting in an

incentive to accelerate the implementation of procedures that involve government officials (Leys, 1965) and reducing the transaction costs of dealing with sluggish systems. This view has found empirical support in Krammer (2019), who studied the introduction of innovative products and the role of corruption in overcoming bureaucratic rigidities, and Xie et al. (2019), who argue that this positive empirical association is more common in developing economies with low overall institutional development.

2 Research questions and hypotheses

In order to deepen the understanding of the formation of SMEs' knowledge-intensive pursuits, this thesis investigates how: (i) aggregate productivity, institutional settings and human capital are associated; (ii) entrepreneurial perception of formal and informal institutional settings associate with firm-level action to engage in R&DI; and (iii) how government efforts through industrial R&DI-oriented policy affect entrepreneurial outcomes. To investigate these queries, six research questions will be explored in this thesis:

1. How are human capital and productivity associated?
2. Are there any positive associations between human capital and institutional factors?
3. How is the entrepreneurial apprehension of institutional settings associated with firm-level R&D engagement in economies where overall institutional development is low?
4. Does bribe solicitation have 'grease the wheel' or 'sand the wheel' effects on firm innovation engagement in developing[2] economies?
5. Is the innovation engagement affected differently by bribe solicitation in domestic versus foreign firms?
6. Does public RD&I policy have positive or negative effects on a firm's short-term performance?

The first article, entitled "The Institutional Environment, Human Capital Development, and Productivity-Enhancing Factors: Evidence from ASEAN Countries" addresses the first two research questions by exploring productivity enhancement, the quality of human capital, and institutional factors among nine ASEAN countries: Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. We analysed these countries for multiple reasons. First, the ASEAN countries are characterised by considerable variation in their institutional settings, heterogeneous cultures, socio-economic contexts, and political development. Second, the ASEAN countries collectively constitute the third-largest economy in Asia and the fifth-largest economy in the world, with a total GDP of around 3.6 trillion US dollars.[3] As the ASEAN region gains more importance in the world economy, the constellation of economic development and institutional settings in these countries warrants further research.

Following the findings of Lucas (1990), Galor and Moav (2004), Cervellati and Sunde (2005), Dunne and Troske (2005), Gómez and Vargas (2012), Che and Zhang (2018), and more, my hypothesis for the first research question is that higher-level human capital has a positive association with factors relevant to productivity, describing the differences in physical capital accumulation, foreign direct investment (FDI) inflows, innovation and the availability of the latest technologies between more and less developed ASEAN countries. The hypothesis for the second research question is that human capital accumulation has a positive association with institutional development (Glaeser et al. 2004 and Ali et al. 2018).

[2] Based on the United Nations Statistics Division (UNStats) classification. Available at: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Funstats.un.org%2Funsd%2Fmethodology%2Fm49%2Fhistorical-classification-of-developed-and-developing-regions.xlsx&wdOrigin=BROWSELINK

[3] Available at: https://www.imf.org/en/Publications/WEO/weo-database/

The second article, entitled "Institutions and R&D engagement of SMEs in Laos. Post-Communist Economies" investigates the association between SMEs' R&D engagement and the institutional setting they themselves perceive in the Lao People's Democratic Republic (hereafter Laos). The institutional setting is observed to have three pillars: (i) political uncertainty; (ii) bribe solicitation by the government; and (iii) frequent tax inspections by the government. The Laos government has made multiple efforts since the beginning of the 21st century to enhance SMEs' productivity through the country's legal and regulatory frameworks. However, little is known about the SMEs' perception of the implementation of regulatory measures in Laos. Moreover, the evidence indicates that the main sources of economic growth are still energy, mineral extraction and mining, low-value-added agriculture, and industry.

Thus, Laos is a good example of an economy where institutional development is low, the government is elite-oriented, and the enforcement of rules and regulations depends on those in power positions. The hypothesis for research question three is that firms that invest in R&D in such institutional settings apprehend institutional quality as being lower through more frequent tax inspections, bribe solicitation and political uncertainty, compared to firms that do not engage in R&D. This follows the findings by Ayyagari et al. (2011) and Aghazada and Ashyrov (2022).

The third paper, entitled "The roles of foreign and domestic ownership in the corruption–firm innovation nexus" investigates the nexus between corruption and innovation among foreign- and domestically-owned firms in developing economies around the world. Differentiation based on ownership is new to the literature on corruption and offers some insightful information. The difference between domestically- and foreign-owned firms that compete in the same market is not ambiguous (Un, 2011) as foreign-owned firms are usually more productive. Nor does this divergence appear to diminish over time because of the differences in financial constraints (Girma et al., 2008; Arnold and Javorcik, 2009; Estrin et al., 2009). This study also addresses the much-debated effects of corruption in the field of bribery studies – 'grease the wheel' effects (e.g., Nguyen et al., 2016; Xie et al., 2019) or 'sand the wheel' effects (e.g., De Waldemar, 2012; Paunov, 2016).

This study addresses research questions four and five. The fourth research question's hypothesis is that, in developing economies where overall institutional quality is low, bribe solicitation has 'grease the wheel' effects on innovation that help firms to overcome bureaucratic barriers and accelerate their innovative activities (Ayyagari et al., 2014; Xie et al., 2019). The hypothesis for the fifth research question is that foreign firms may experience bribe solicitation more as they are less restricted by financial constraints (Girma et al., 2008).

The final paper, entitled "How the EU Cohesion Policy targeted at R&D and Innovation impacts the Productivity, Employment, and Exports of SMEs in Estonia" investigates the short-term effects of the 2014–2020 European Cohesion Policy Programme on Estonian firms' productivity, employment, and export outcomes. Public support for R&DI can be viewed through the prism of market failures. SMEs' ability to implement a policy of intellectual property protection is often limited, restricting the appropriability of innovation returns (Arrow, 1962). Consequently, this may lead to underinvestment in R&DI without the support of public grants (Acs and Audretsch, 1990). The primary challenge for public R&DI-targeting support programs is the trade-off between achieving short-term measurable gains that improve the performance of beneficiaries and the

long-term structural effects that might not promote entrepreneurial incentives to innovate (Hottenrott et al., 2017).

The literature on the effectiveness of Cohesion Policy (CP) outcomes is broad, expanding and reports highly mixed results (Dall'Erba and Le Gallo, 2008; Ramajo et al., 2008; Hagen and Mohl, 2011; Pienkowski and Berkowitz, 2016; Dall'Erba and Fang, 2017). The ambiguous results are driven by two-dimensional heterogeneity. The first dimension of this heterogeneity stems from public support targeting a highly diversified set of beneficiaries (Rodríguez-Poze and Fratesi, 2004; Bachtrögler et al., 2020; Fattorini et al. 2020). The second dimension derives from the regional differences in the economic systems, regulatory implementations and entrepreneurship ecosystems (Cappelen et al., 2003; Ederveen et al., 2006; Farole et al., 2011; Becker et al., 2013; Bachtler, 2014; Bachtrögler et al., 2020). Thus, the article addresses research question six with the hypothesis that the public research, development, and innovation (RD&I) policy promotes firms' short-term performance, following the results published by Benkovskis et al. (2018) regarding Latvian firms.

3 Data and methodology

This thesis uses both macro- and micro-level data retrieved from various databases. The macro-level data comes from the World Bank (WB), Penn World Tables version 10 (PWT), World Economic Forum Global Competitiveness Index (WEF GCI), World Bank Governance Indicators (WGI), and the Global Innovation Index (GII) databases. For exploring the micro-level responses, the thesis mainly uses WB Enterprise Survey data, accompanied by data from Statistics of Estonia and Enterprise Estonia for public grants.

3.1 Evaluating macro-level associations between institutions and human capital

The first article, entitled "The Institutional Environment, Human Capital Development and Productivity-Enhancing Factors: Evidence from ASEAN Countries" addresses research questions one and two by studying the country-level associations between three domains (human capital, productivity, and institutional quality) among nine ASEAN countries. The data for these domains were gathered from WB, PWT, and WEF GCI databases. Due to data availability, the study covers the years from 2007 until 2017 inclusive.

Based on studies by Barro (2001), Galor and Moav (2004), Cervellati and Sunde (2005), Lee et al. (2010), Ali et al. (2018), and Maneejuk and Yamaka (2021), the knowledge bases of the countries are described using data on tertiary education enrolment, education quality, human capital index, the availability of scientists and engineers, and the percentage of the population using the Internet. Variables such as capital stock, foreign direct investment inflows, the output side of real GDP, an innovation index, and the availability of the latest technologies are used to identify the productivity-enhancing factors and thus capture each country's level of wealth through economic activity, capital inflows and the overall level of real capital stock required from physical capital accumulation to carry out innovation (see Alguacil et al., 2008; Fu et al., 2011; Iamsiraroj and Ulubaşoğlu, 2015). The latest technologies' level of availability is used as a proxy in this study for capturing the technological base for innovating (Romer, 1990; Rivera-Batiz and Romer, 1991).

To capture the productivity-enhancing institutional setting, measures of economic freedom, political stability, voice and accountability, and intellectual property protections are used. Economic freedom comprises government size, regulatory efficiency, openness, and the rule of law to protect rights for doing business and to enable benefits to be derived from open markets (see Romer 1990). Intellectual property protection, political stability, and voice and accountability, on the other hand, capture the legal environment required for inventors to seek property protection for their inventions (Yang and Maskus, 2001; Guisan, 2009; Hall et al., 2010; Lin et al., 2010; Xu et al., 2016).

The empirical evaluation is carried out by using the canonical correlation method, which belongs to a family of multivariate statistical methods that assess the linear relationships between dependent and independent variable pairs denoted as Y and X, respectively. The dependent variable pairs explored in this study include the productivity and institutional quality-related set of variables. The independent set of variables includes variables related to human capital quality. The canonical variates of the model are defined as $(A_i, B_i), i = 1, .., n$. The canonical correlation method maximises the correlation $\rho_i^* = (cov(A_i B_i))/\sqrt{(var(A_i)var(B_i))}$ between the canonical pairs. The simplified framework of canonical correlation is given in Figure 3, below.

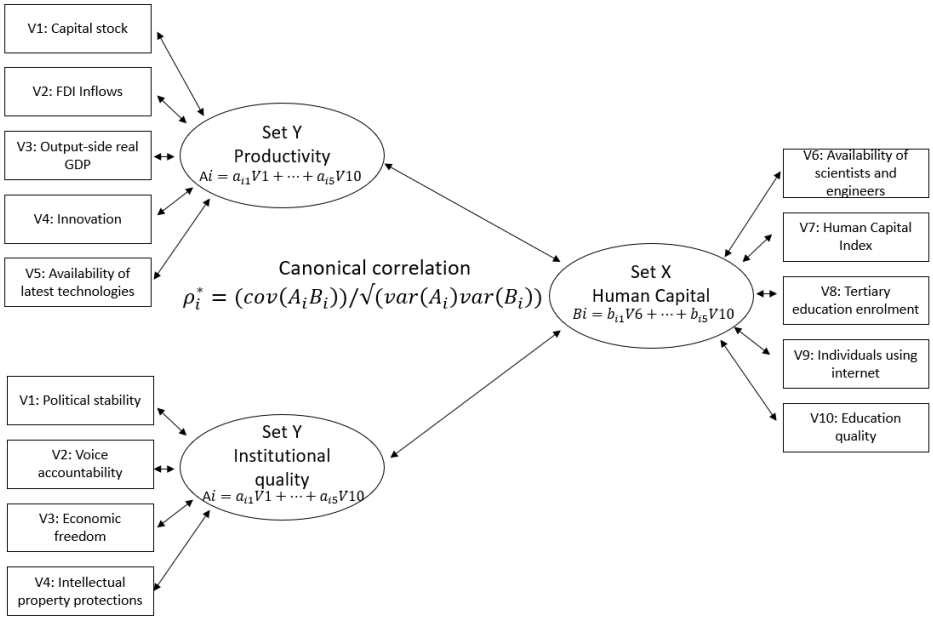

Figure 3. Canonical correlation estimation framework.
Source: Author's creation based on Androniceanu et al. (2020).

Like multiple linear regression, canonical correlation is suitable for analysing associations between pairs of variables using linear combinations, but it allows multiple intercorrelated outcome variables accommodating a more complex set of multivariate relationships when exploring the associations between productivity, institutional quality, and human capital. Unlike many of the linear regression methods, including panel data and time-series models, canonical correlation effectively handles high dimensionality in a limited sample size. Institutional changes are mostly evolutionary, and the variance arises over a longer time span. The variation in short country-level panels is drawn from cross-country heterogeneities in institutional settings. Given the limitations in institutional variation and in sample size, canonical correlation enables the researcher to explore the associations between the sets of variables characterising the institutional setting and the productivity-enhancing capacities of human capital and innovation, in order to provide correlations between the generalised synthetic dimensions of interest.

3.2 Bribery and R&DI

Articles two and three, entitled "Institutions and R&D engagement of SMEs in Laos" and "The roles of foreign and domestic ownership in the corruption–firm innovation nexus" respectively, focus on the firm-level apprehension of the institutional setting, and the effects of bribe solicitation on firms' R&DI engagement. To do so, both studies use the firm-level data retrieved from the WB Enterprise Surveys database. The first of the two studies focus on the R&D engagement of 614 private firms in the emerging economy of Laos. The data covers the survey years 2016 and 2018. The dependent variable was a binary R&D variable, indicating whether the firm had reported R&D investments. The independent variables that reflect institutional perception included the ordinal variable of perceived political uncertainty as an obstacle to doing business (following

Barro, 1991; Lin et al., 2010; and Xu et al., 2016), and a nominal number of tax inspections by government officials. Additional firm-level variables, reflecting the firm's abilities to invest in R&D, included firms' age, number of employees, annual sales revenues, apprehension of access to credit and availability of sufficiently educated human capital, and the binary variable of foreign ownership status derived from a 50%-or-more foreign ownership threshold.

The second of the two studies investigated innovation engagement more broadly by including firm-level responses from 4,118 privately owned firms from 34 developing[4] economies around the world. The innovation engagement was measured in three ways: (i) product innovation engagement, (ii) process innovation engagement, and (iii) overall innovation engagement that combined those definitions in line with earlier studies like those of Van Beveren and Vandenbussche (2010), Capitanio et al. (2010), Damijan et al. (2010), Ayyagari et al. (2011), Goedhuys and Veugelers (2012), Michailova et al. (2013), and Cirera and Sabetti (2019), among others. The firms were classified into categories of foreign or domestic ownership using a 10% ownership threshold, following Ashyrov and Masso (2020). In addition, in this study, the sample was restricted to exporting firms only, first to avoid potential endogeneity stemming from the "learning from exporting" hypothesis (Bratti and Felice, 2012; Fabling and Sanderson, 2013; Rodil et al., 2016) and second due to evidence that exporting firms are more productive than their non-exporting counterparts (Basile, 2001). Additional firm-level control variables included the age of the firm, the group indicator (if the firm is part of a bigger establishment), number of employees, sales, firms' product portfolio diversity, possession of quality certification, skilled labour proportion, engagement in R&D, tax administration as self-perceived obstacle for doing business, and indicators of whether the firms have interacted with government officials to obtain electricity-related infrastructure connections (De Rosa et al., 2015) or import licenses. To account for the country-level fixed effects, variables like Purchasing Power Parity, adjusted GDP per Capita, population, export as a percent of GDP, rule of law, and innovation indices from WB, WGI, and GII databases were included in addition to the country identification variable.

A common key dependent variable in both studies is the self-reported dichotomous bribe variable that reflects whether the firm has experienced informal gifts or informal payment requests from government officials. According to Lin et al. (2010), informal payments or gift requests by government officials reflect the government's avarice, leading to an increase in the cost of doing business and lowering returns to R&DI. It is important to note that the bribe variable has potentially endogenous properties concerning firms' R&DI engagement as innovating may lead to a need to obtain different permits or licenses that increase interactions with government officials (Xie et al., 2019).

In addition to the endogeneity problem, the measures from both studies suffer from reporting biases common in working with survey data. First, the R&DI measurement is derived based on the respondents' apprehension of innovation. Both samples are dominated by small and medium businesses with low overall R&D intensity. This may lead to measuring innovation that is incremental rather than substantial. Second, the data suffer from missing responses. Although WB surveys are conducted in a way that provides full confidentiality to responders, the bribe variable poses many missing observations that may be deliberately omitted. To alleviate the possible bias stemming

[4] Based on the United Nations Statistics Division (UNStats) classification.

from the self-reported data that are not missing at random (Rubin, 1976 and 1978), multiple imputations are used to estimate the statistically possible responses to missing values.

Because of the limited sample size, the potential endogeneity between the dependent variable and the bribe variable, and the availability of mostly ordinal and binary independent variables in the first study, full Bayesian inference logistic regression with a Bernoulli distribution was used to control for the possible randomness of parameter estimates and separability between variables. The posterior distribution was sampled using the Hamiltonian Monte Carlo (HMC) 'no-U-turn' sampler (NUTS). The first two estimations used normal and Student's t-distribution vague priors to identify problems with the model estimations and sample the posterior distribution. In the third estimation, the rescaling of estimations was undertaken adopting Gelman et al.'s (2008) suggestion to use a normal distribution generic prior for binary independent variables and a weak Student's t-distribution prior for all other independent variables (Gelman et al., 2008). The fourth estimation used weakly informative empirical priors that were derived from the expected associations between dependent and independent variables based on the association found in the literature. A simplified graphical presentation of the Bayesian logistic regression with Bernoulli distribution is given below, in Figure 4.

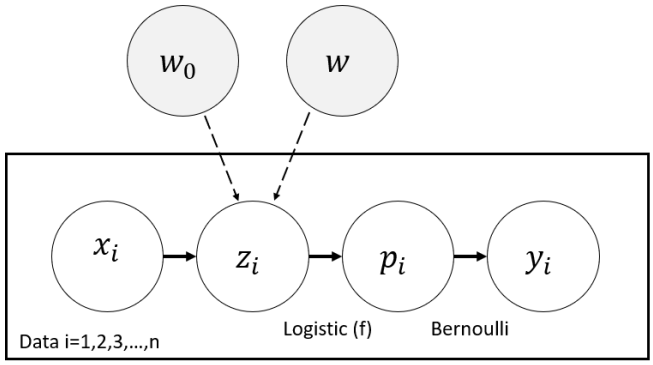

Figure 4. Simplified graphical presentation of Bayesian logistic regression with a Bernoulli distribution.
Notes: x_i denotes the original information captured in the data. The prior inference is denoted by w for independent variables and w_0 for the intercept, which in a general form notation can be formulated as $w \sim N(\mu, \sum)$, where μ represents the prior mean and $\sum$ represents the prior standard deviation. $z_i = w^T x_i$ denotes the pseudo data, and the discriminative probabilistic linear classifier is formulated as $Pr(y_i = 1|x_i) = \frac{1}{1+exp^{-z}} = \lambda(z_i)$. Thus, $y_i \sim Bernoulli\ (p_i)$ denotes the estimated posterior distribution estimated from the exact Bayesian inference for logistic regression with a non-conjugate prior, formulated as $Pr\ (y_i = 1|w^T x_i = \ \hat{}(w^T x_i)p(w)dw$
Source: Author's creation based on Tasane et al. (2023).

The second study, however, addressed the identification of the causal relationship of bribe solicitation on a firm's innovation engagement by using recursive bivariate probit regression (Lewbel et al., 2012; Filippini et al., 2018). The recursive bivariate probit enables analysts to address endogeneity through a system of simultaneous equations, allowing correlation of the error terms, which in separate estimations would lead to inconsistent estimates.

The recursive bivariate probit is a class of simultaneous equation estimator. Recursive bivariate probit enables the joint estimation of two dichotomous choice probit models, allowing the correlation of error terms that would lead to inconsistent estimates if estimated in the single equation model, due to endogeneity. The system of the simultaneous equations is given in formulae (1)-(3), below.

$$D^* = X\beta_D + Z\gamma + \epsilon_2, \quad D = \mathbb{I}(D^* > 0) \tag{1}$$

$$Y^* = X\beta_Y + D\alpha + \epsilon_1, \quad Y = \mathbb{I}(Y^* > 0) \tag{2}$$

$$\text{so that } \rho = cor(\epsilon_1, \epsilon_2) \neq 0 \tag{3}$$

Y^* and D^* represent latent variables representing the probability of the baseline outcome of engaging in innovation and the probability of endogenous dichotomous action of engaging in bribery, respectively. X denotes a set of common covariates included in both innovation and bribe engagement equations, and Z denotes the instruments of the endogenous choice of engaging in bribery. $\mathbb{I}(\cdot)$ denotes the indicator function. The graphical illustration of the recursive bivariate probit is given in the Figure 5 below.

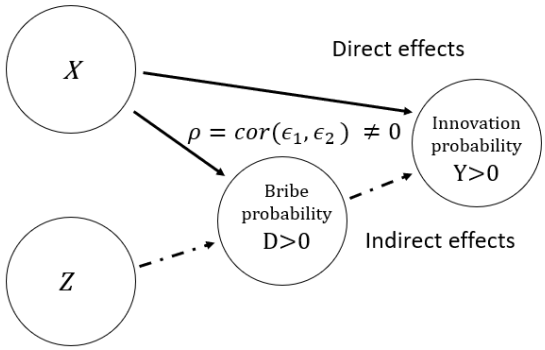

Figure 5. Recursive bivariate probit framework.
Source: Author's creation.

3.3 Effects of public innovation policy on firms' performance

The fourth article of this thesis is entitled "How the EU Cohesion Policy targeted at R&D and innovation impacts the productivity, employment and exports of SMEs in Estonia" investigates the question posed by its title. The study uses a total of six different data sources, merged into one comprehensive dataset. The funded projects and beneficiaries' data for the 2014–2020 and 2007–2013 program periods were retrieved from the Estonian Ministry of Finance. National support data for developing the competitiveness, smart specialisation and export capacity of Estonian companies were retrieved from the Enterprise Estonia database. Estonian companies' registry and business registry data were accessed through the Statistics of Estonia research environment. The main observed periods covered the years from 2014 to 2019. These controls used registry data on Estonian companies that covered business demographic information including company size, age, ownership, sector and location; financial and accounting information; and the

companies' records in exporting. The Estimation sub-samples were formed on the support activity level, including companies that met support eligibility requirements, while outliers were removed using uni- and multivariate outlier detection (blocked adaptive computationally efficient outlier nominators: see Billor et al., 2000).

The analytical framework relied on estimating the causal effects of the policy intervention, setting up a counterfactual that constituted the hypothetical outcome of the treated unit had it not received treatment. The underlying framework for causal inference was based on the potential outcome model designed by Rubin (1974). In observational studies, including quasi-experimental designs, the fully randomised treatment condition was not satisfied, and additional measures needed to be taken to meet the unconfoundedness assumption, which implies that treatment assignment is independent of the observed outcomes. There is a substantial and rapidly expanding body of methodological research that has proposed solutions for correcting the selection bias that is conditional on observables, allowing the treatment to be estimated under unconfoundedness. These methods include matching techniques, regression adjustment with inverse probability weighting (IPW), regression discontinuity design, difference-in-difference, imputation and projection techniques, and hybrid-class methods (Rosenbaum and Rubin, 1983; Bickel et al., 1993; Wooldridge, 2007; Imbens and Wooldridge, 2009; Cattaneo, 2010; Imbens and Rubin, 2015; Abadie and Cattaneo, 2018).

This research uses some properties of the quasi-experimental design; however, since support is allocated nonrandomly, the study had to impose controls for the selection into the treatment (see Czarnitzki and Lopes-Bento, 2014 for selection bias) and make adjustments to set up the counterfactual. Consequently, we estimated the empirical analysis of the causal inference in two steps. The first step included calculating generalised propensity scores (GSP) for selection into treatment D, which corresponded to receiving public R&DI support. The generalised propensity score was calculated on covariates dated T – 1 from the treatment D.

The second step estimated the semi-parametric inverse probability weights (IPW) using the novel efficient influence function estimator (EIFE) proposed by Cattaneo (2010). The efficient influence function estimator used the covariates dated T – 2 from the outcome Y to avoid potential endogeneity between the dependent and independent variables. Combining the regression adjustment and matching techniques made it possible to meet the assumptions of unconfoundedness along with offering the benefits of the semi-parametric approach, circumventing the rigidity of assumptions about the functional form. The simplified estimation strategy is given in Figure 6, below.

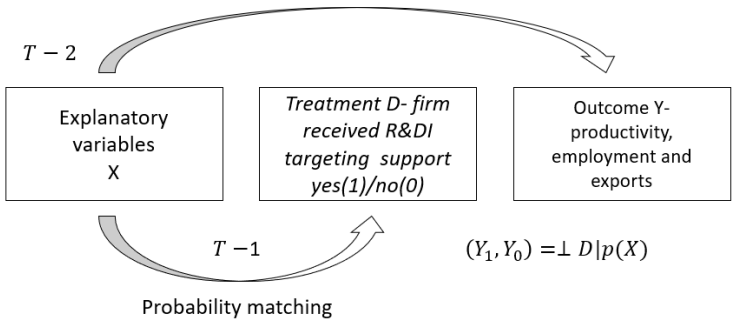

Figure 6. Simplified estimation strategy showing the effects of Cohesion Policy targeting R&DI using the semiparametric efficient influence function estimator.
Source: Author's creation.

4 Findings and conclusions

This thesis investigates how human capital, institutional factors and bribe solicitation are associated with the extent to which SMEs are innovative. The four publications included in this thesis enable us to understand the role of human capital and institutional settings on different economic levels and through different institutional concepts. As the main focus of the studies is on the transition context of rapidly growing ASEAN countries or of more advanced emerging economies, this thesis contributes to institutional studies by shedding light on: (i) what the differences are in human capital and productivity-enhancing factors between high-income countries and rapidly growing ASEAN countries in transition; (ii) how self-perceived institutional environment and bribe solicitation relates to SMEs' R&DI engagement; and (iii) how government R&DI policy impacts SMEs' labour productivity, employment and exports.

The first article contributes to understanding how institutional factors and the quality of human capital are associated with productivity-enhancing factors. By focusing mainly on nine ASEAN countries, which exhibit high variance in income per capita and very heterogeneous institutional backgrounds, the results derived from the study sample show that countries with high GDP per capita in constant national prices exhibited a high association between R&D-relevant human capital development, productivity-enhancing factors, and institutional strength. This association suggests that the quality of human capital has enabled these countries to attract FDI, technology adoption, innovation and the institutional development required for sustainable economic growth. On the other hand, the transition countries in the sample, despite demonstrating rapid economic growth, are still heavily dependent on low value-added physical capital accumulation in sectors where there is a relatively low level of technology adoption and even less innovation.

Although technology adoption has been understood as one of the key elements for achieving economic growth and overcoming poverty gaps, it requires a sufficient level of human capital to succeed. The developments in human capital accumulation, however, appear both to be asymmetric in time and associated with the countries' institutional backgrounds, confirming hypotheses one and two. The main policy implication of these results concerns human capital accumulation through the quality of education and the availability of a workforce with top-level skills.

The second and third articles contribute to scholarly understanding of the association between firms' institutional perceptions, bribe solicitation, and willingness to engage in high-uncertainty R&DI activities. The second paper's empirical findings demonstrate that in Laos, an economy with a weak institutional setting, firms that engage in R&D experience more government bribe solicitation and need to deal with cumbersome business regulations. Companies engaging in R&D investments are more frequently subject to tax inspections associated with time-tax and increased operations with government officials. In addition, R&D-investing firms perceive greater political uncertainty, which is also associated with the apprehension of property protections. This confirms the third hypothesis, with policy implications concerning the potential pitfalls of cumbersome business regulations and the need to strengthen the protection of property rights.

The third article also deepens the understanding of associations with bribery and R&DI engagement by examining it through the lens of firms' ownership. The results confirmed this paper's fourth hypothesis and revealed that bribery serves as a 'grease the wheel' mechanism facilitating innovation regardless of firms' ownership status in developing

economies. As foreign-owned firms generally have better access to external finance, they can better accommodate the costs of bribery to get things done than domestically owned firms, as assumed in the fifth hypothesis. The mechanism for domestically owned firms, however, is slightly different: they are less restricted in interacting with local public officials in their home country and are more familiar with the culture of business–government relations and possible loopholes in the legislation. It is important to note, however, that the 'grease the wheel' hypothesis of the corruption and innovation nexus holds true only in the context of the sample of countries included in this study and the cross-sectional setting of the data while denying the possibility of extending these results to examine the long-term effects that corruption may have on innovation.

In some cases, bribery may generate competitive distortions and give a competitive advantage to specific firms. In the case of innovation, this competitive advantage may persist if it serves dominant and monopolistic firms. As a result, this study's findings underscore the importance of developing countries finding institutional and policy solutions to coordination failures where the company-level rational choice to bribe leads to market friction, negative externalities, and suboptimal development at the country level.

The fourth paper contributes to the understanding of how an R&DI-targeted Cohesion Policy supports firm-level short-term labour productivity, employment, and exports. The results indicate that while the R&DI supports have positive impacts on firms' labour productivity, the results for employment outcomes are moderate, while the exporting outcomes are ambiguous. As a result, the study only partially confirms the sixth hypothesis by revealing desirable outcomes in labour productivity for R&DI-targeting support programs given the lagged and uncertain outcomes of R&DI, which may also justify the inconclusive effects for exporting.

There are several limitations to the findings of this thesis. First, the connections between human capital, institutional strength and productivity are explorative and do not address causality, which would enrich the results significantly. Second, the role of formal and informal institutions is addressed by mainly relying on the perception of the individuals representing the entrepreneurial bodies, and the results reflect the short-term effects of that perception. Third, the effects of government intervention through R&DI policy are measured by relying only on quantitative data. Thus, future research could add additional value by addressing the causality that exists between aggregate productivity, human capital, and institutional settings, and observing the long-term effects of institutional perception and R&DI outcomes. Regardless, this thesis offers policy implications that underscore the roles of institutional strength and human capital development in generating productivity growth, warranting the entrepreneurial conditions to engage in high-uncertainty R&DI activities that are indispensable for long-term sustainable development.

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Abstract
Institutions and the innovativeness of SMEs

Economic development is a focal point of economic research and policymaking. Entrepreneurship, especially knowledge-intensive entrepreneurship, is one of the core elements driving economic growth through job creation, product diversification and competition. R&DI product differentiation is costly, characterised by high uncertainty, and capital gains emerge only after a certain amount of time has elapsed. But why are businesses in some countries more innovative than in other countries?

This thesis aims to investigate the nexus between the institutional setting and the innovativeness of SMEs by exploring: (i) whether aggregate productivity, institutional setting and human capital are associated; (ii) entrepreneurial perception of formal and informal institutional settings associate with firm-level action to engage in R&DI; and (iii) whether government efforts through industrial R&DI-oriented policy affect the entrepreneurial outcomes. The core focus of this thesis lies in observing institutional settings in the context of ASEAN or other developing economies but also takes advantage on Estonian R&DI policy enforcement outcomes.

This thesis consists of four published articles that together address six research questions and hypotheses. The first article explores how human capital and institutional strength are related to productivity-relevant factors in nine ASEAN countries, described in terms of high variance in wealth levels. The second article explores the association between firm-level self-perceived institutional strength and bribe solicitation, and its effect on research and development engagement in the emerging economy of Laos. The third article addresses the nexus between bribe solicitation and innovation engagement in foreign- and domestically owned firms operating in developing economies. The fourth article studies the impacts of the European Union Cohesion policy targeting R&DI on Estonian SMEs' short-term labour productivity, employment, and export outcomes.

Various data sources are used throughout the studies included in this thesis. The macro-level data comes from the World Bank, Penn World Tables version 10, World Economic Forum Global Competitiveness Index, World Bank Governance Indicators, and Global Innovation Index databases. The firm-level data is mainly World Bank Enterprise Survey data, but also comes from Statistics of Estonia and Enterprise Estonia for public grants. The methods used in this study include (i) canonical correlation for finding an association between variable groups in short, macro-level panels; (ii) full Bayesian inference logistic regression and recursive bivariate probit regression to explore the relationship between the firms' self-perceived institutional setting and bribe solicitation, along with research, development and innovation contaminated by the endogeneity; and (iii) a two-level efficient influence function estimator, to evaluate the treatment effects of government research, development and innovation policy.

The results of these studies indicate that, based on the example of the nine ASEAN economies included in the sample, the quality of human capital is indispensable for promoting the productivity-enhancing factors like foreign direct investments, technology adoption, innovation, and institutional development required for sustainable economic growth. The transition countries in the sample, which are characterised by lower wealth levels, are still more heavily dependent on low value-added physical capital accumulation in sectors characterised by low levels of technology adoption and overall innovation. Firms that operate in developing economies and engage in high-uncertainty R&DI

activities tend to experience more government bribe solicitation, perceive institutional quality as lower, and deal with more cumbersome business regulations that require increased interactions with government officials. The differentiation based on firm ownership and experiences of bribe solicitation does not indicate that domestically owned firms experience bribe solicitation differently from foreign-owned firms, which generally have better access to external finance and can better accommodate the costs of bribery. The results of the government policy aiming to promote firms' R&DI indicate positive impacts of government efforts and reveal desirable outcomes for firms' subsequent short-term labour productivity – but not on employment, or on exports, which depend on the time-lagged outcomes of innovation.

The main policy implications arising from this study derive from the finding that human capital along with institutional strength are indispensable for promoting knowledge-intensive economic development. Since returns on the R&DI are uncertain and emerge only after some considerable time, these findings underscore the importance for developing countries of finding institutional and policy solutions to coordination failures, which lead to market friction, negative externalities, and suboptimal development at the country level. Along with strengthening institutional settings, positive R&DI policy, which alleviates credit constraints for innovating, promotes entrepreneurial outcomes for growth and development. The results of this thesis contribute to enhancing the understanding of the importance of institutional settings to country-level differences in wealth and explain how institutional settings associate with firms' R&DI activities.

Lühikokkuvõte
Institutsioonid ning väikeste ja keskmise suurusega ettevõtete innovatsioonivõimekus

Majanduskasv ja -areng on majandusuuringute ja poliitikate kujundamise üks põhifookuseid. Ettevõtlussektor ja selle teadmusmahukuse kasv on majandusarengu üheks olulisemaks komponendiks, luues uusi kõrge lisandväärtusega töökohtasid ja panustades konkurentsivõime kasvu läbi kaupade- ja teenuste mitmekesistumise ning lisandväärtuse kasvu. Teadus- ja arendustegevusel ning innovatsioonil tuginev kaupade- ja teenuste väärindamine on aga kulukas, tegevuse tulem on ebakindel ja tasuvus saabub üldiselt märkimisväärse viitajaga. Jääb aga küsimus, et miks on mõned riigid oma ettevõtlussektori näol innovatiivsemad kui teised?

Käesolev doktoritöö keskendub institutsioonide ja väikeste ning keskmise suurusega ettevõtete innovatsioonivõimekuse vaheliste seoste uurimisele, käsitledes: (I) tootlikkusega seotud tegurite, institutsioonide ja inimkapitali vahelisi seoseid; (II) kuidas ettevõtete poolt tunnetatud formaalne ja mitteformaalne institutsionaalne keskkond on seotud väikeste ja keskmise suurusega ettevõtete teadus- ja arendustegevuse ning innovatsiooniga; ja (III) kuidas riiklik teadus- ja arendustegevuse ning innovatsioonipoliitika mõjutab väikeste ja keskmise suurusega ettevõtete lühiajalisi majandustulemusi. Käesolev doktoritöö keskendub peaasjalikult Kagu-Aasia Maade Assotsiatsiooni ja muude arengumajanduste näidetele, aga ka Eesti teadus- ja arendustegevuse ning innovatsioonipoliitika rakendamise tulemustele.

Doktoritöö koosneb neljast artiklist, mis on avaldatud rahvusvahelistes eelretsenseeritavates teadusajakirjades. Esimene artikkel uurib inimkapital ja institutsionaalse kvaliteedi seoseid tootlikkust mõjutavate teguritega üheksa Kagu-Aasia Maade Assotsiatsiooni riigi näitel, mida iseloomustab kõrge variatsioon jõukuse tasemetes. Teine artikkel uurib ettevõtte tunnetust institutsionaalse kvaliteedi osas, altkäemaksu ning teadus- ja arendustegevusega tegelemise vahelisi seoseid Laose näitel. Kolmas artikkel uurib kuidas altkäemaksujuhtumid on seotud välis- ja kodumaises omandis olevate ettevõtete innovatsioonitegevusega erinevate arenevate riikide näitel. Neljas artikkel keskendub Euroopa Liidu Ühtekuuluvuspoliitika teadus- ja arendustegevusele ning innovatsioonile suunatud ettevõtlustoetuste lühiajalist mõju Eesti väikeste ja keskmise suurusega ettevõtete tööjõutootlikkusele, tööhõivele ja ekspordile.

Doktoritöö raames läbi viidud uurimustes kasutatakse erinevatest andmebaasidest pärinevaid andmeid. Makrotasandi andmed pärinevad Maailmapanga, Penn World Tables 10, Maailma Majandusfoorumi globaalse konkurentsivõime indeksi, Maailmapanga valitsemisnäitajate ja Globaalse Innovatsiooni Indeksi andmebaasidest. Ettevõtte tasandi andmed pärinevad peamiselt Maailmapanga ettevõtete uuringust, aga ka Eesti Statistikaametist ja Ettevõtluse Arendamise Sihtasutuse toetusandmetest. Doktoritöös kasutatud meetodid hõlmavad: (I) kanoonilist korrelatsiooni leidmaks seoseid muutujate rühmade vahel lühikestes makrotasandi paneelides; (II) Bayesian logilist regressiooni ja rekursiivset kahemõõtmelist probit regressiooni, et uurida ettevõtete poolt tunnetatud institutsionaalse keskkonna kvaliteedi, altkäemaksu ning teadus- ja arendustegevuse ning innovatsiooniga tegelemise vahelisi seoseid endogeensustingimustes; ja (III) kahetasandilist mõjusa hindamise meetodit hindamaks Euroopa Ühtekuuluvuspoliitika teadus- ja arendustegevuse ning innovatsioonipoliitika mõju ettevõtete majandusnäitajatele.

Käesolevas töös käsitletud uurimuste tulemused näitavad üheksa Kagu-Aasia Maade Assotsiatsiooni majanduse näitel, et inimkapitali kvaliteet on möödapääsmatu tootlikkusega seotud tegurite, nagu välisinvesteeringud, tehnoloogiasiire, innovatsioon ja institutsionaalne areng, soodustamiseks ning sellest tõukuva jätkusuutliku majanduskasvu saavutamiseks. Valimisse kuulunud üleminekuriigid, mida iseloomustab madalam jõukuse tase, sõltuvad endiselt enam madalama lisandväärtusega füüsilise kapitali akumulatsioonist sektorites, mida iseloomustab omakorda vähene tehnoloogiasiire ja madal innovatsiooni tase. Ettevõtted, kes tegutsevad arenevatel turgudel ja tegelevad teadus- ja arendustegevuse ning innovatsiooniga kogevad tõenäoliselt sagedamini korruptsiooni, peavad institutsionaalset kvaliteeti madalamaks ja peavad tegelema keerukate ning kurnavate regulatsioonidega, mis nõuavad tihedat läbikäimist riigiteenistujatega. Ettevõtete eristamine omandivormi järgi aga ei viita sellele, et kodumaises omandis olevad ettevõtted erineksid oluliselt välisomandis olevatest ettevõtetest, kellel on üldiselt väiksemad kapitalipiirangud läbi omandisuhete ja suudaksid seeläbi korruptsiooniga seonduvate kuludega paremini toime tulla. Riiklik teadus- ja arendustegevusele ning innovatsioonile suunatud ettevõtluspoliitika näitab positiivseid lühiajalisi mõjusid ettevõtete tootlikkuse kasvule ning aitab vähendada teadus- ja arendustegevuse ning innovatsiooniga seotud kapitalipiiranguid. Samas nimetatud poliitika lühiajalised mõjud ettevõtete tööhõivele ja ekspordile ei leia kinnitust tulenevalt teadus- ja arendustegevuse ning innovatsiooni tulemuste viitajaga avaldumisest.

Käesolevast doktoritööst tõukuvad poliitikasoovitused hõlmavad inimkapitali ja institutsionaalse arengu olulisust teadmistepõhise majandusarengu saavutamisel. Võttes arvesse teadus- ja arendustegevusele ning innovatsioonile omast ebakindlus tegevuste tulemuslikkuses ning viitajaga kaasnevaid tulusid, ilmestavad käesoleva töö leiud institutsionaalsete ja poliitiliste lahenduste leidmise olulist koordinatsiooniprobleemidele, mis põhjustavad turu kõrvalekaldeid, negatiivseid välismõjusid ja takistavad seeläbi teadmusmahukat majandusarengut riiklikul tasandil. Institutsionaalse raamistiku tugevnemisel on oluline roll teadus- ja arendustegevuse ning innovatsioonipoliitikal leevendamaks ettevõtete uuendustegevustega seotud kapitalipiiranguid ja tagamaks nende ettevõtete jätkusuutlik toimimine. Selle lõputöö tulemused aitavad paremini mõista institutsionaalse keskkonna rolli jätkusuutliku majanduskasvu saavutamisel läbi ettevõtlussektori, näidates kuidas erineva jõukustasemega riigid erinevad oma inimkapitali- ja institutsionaalse kvaliteedi poolest ning käsitledes kuidas institutsionaalne keskkond seostub ettevõttetasandi teadus- ja arendustegevuse ning innovatsiooniga.

Appendix 1

THE INSTITUTIONAL ENVIRONMENT, HUMAN CAPITAL DEVELOPMENT AND PRODUCTIVITY-ENHANCING FACTORS: EVIDENCE FROM ASEAN COUNTRIES

Publication I

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ORIGINAL ARTICLE

The Institutional Environment, Human Capital Development, and Productivity-Enhancing Factors: Evidence from ASEAN Countries

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Abstract

We explored the nexus between the quality of human capital, productivity-enhancing factors, and the quality of institutions in nine Association of Southeast Asian Nations (ASEAN) countries using canonical correlation and principal component analysis of country-level data for 2007–2017 from the World Bank, World Economic Forum, and Penn World Tables databases. We found that an unequal development of human capital in the ASEAN countries is clearly linked to their heterogeneous institutional conditions and that the quality of human capital drives technology absorption and innovation. The four transition economies in the region—Laos, Cambodia, Vietnam, and Myanmar—are facing particularly difficult challenges in developing institutional environments that stimulate human capital development to reach higher levels of knowledge intensity of their economies and achieve the resulting competitive advantages.

Keywords: institutions; human capital; knowledge; development; Southeast Asia

JEL Classification: O1; O4

Introduction

The Association of Southeast Asian Nations (ASEAN) countries are geographically close but exhibit vast differences in their level of economic development. According to 2021 statistics, the per capita income of Singapore, the richest ASEAN country, is more than 50 times that of Myanmar, the poorest.[1] In parallel, ASEAN countries are characterised by large variances in their institutional environments, driven by their heterogeneous cultural, socio-economic, and political development paths. Efficient institutions are however key in building the knowledge base and supporting investments and innovation for the achievement of competitive advantages in the global economy. In this study, we sought to uncover how various characteristics of human capital, productivity enhancement, and institutional environments are linked in the diverse ASEAN economies to pinpoint through a comparative perspective and from a new angle some particular sets of challenges that those countries are facing in their economic development.

Numerous theoretical and empirical studies have concluded that technology adoption and innovation are essential for long-term economic growth and development (see, e.g. Abramovitz 1993; Coe and Helpman 1995; Funke and Strulik 2000; Grossman and Helpman 1991; Hasan and Tucci 2010; Liu and Xia 2018; Maradana *et al.* 2017; Bilbao-Osorio and Rodríguez-Pose 2004; Pece *et al.* 2015; Segerstrom 1991; Thompson 2018). There is therefore a growing emphasis on understanding the factors, such as human capital development and institutional setting, that drive technological adoption and undertaking innovations. Human capital is considered one of the prerequisites for implementing new technologies or technological improvements and is indispensable in innovation (Cervellati and Sunde 2005; Che and Zhang 2018; Cosar 2011; Danquah and Amankwah-Amoah 2017; Dakhli and De

[1]https://data.worldbank.org/indicator/NY.GDP.PCAP.KD?end=2021&locations=KH-LA-VN-MM-TH-PH-ID-SG-MY&start=1960

Clercq 2004; Dunne and Troske 2005; Funke and Strulik 2000; Galor and Moav 2004; Gómez and Vargas 2012; Keller 1996; Nelson and Phelps 1966; Bilbao-Osorio and Rodríguez-Pose 2004). Human capital development and accumulation, however, are highly dependent on the existing institutional setting (Acemoglu *et al.* 2001; Ali *et al.* 2018; Glaser *et al.* 2014; North and Thomas 1973; Robinson and Acemoglu 2012). Economic development in low-income countries is often constrained by a lack of technological advancement, which is caused by a shortage of human capital that could be engaged in absorbing and utilising new technologies, driven by the efficiency of institutions (e.g. Acemoglu and Dell 2010). How those interrelated phenomena have manifested in the diverse context of ASEAN economies is not yet well understood.

The ASEAN countries collectively constitute the third largest economy in Asia and the fifth largest economy in the world, after the United States, the European Union, China, and Japan, with a total GDP of approximately $3.6 trillion.[2] Although the importance of the ASEAN countries in the global economy is increasing, the differences in the levels of development and wealth distribution within the member countries are huge. Six of the ASEAN countries account for 86 per cent of the total ASEAN GDP, and although the four least developed ASEAN countries—Cambodia, Laos, Vietnam, and Myanmar—have had overall higher growth rates since 2008, their combined GDP is 14 per cent of the total GDP of the ASEAN region (International Monetary Fund, World Economic Outlook database, 2022). As the ASEAN region becomes more important in the world economy, the patterns of economic development, human capital development, and institutional setting in these countries warrant further study so that the development paths and challenges in these heterogeneous economies can be better understood.

A key objective of ASEAN is to seek deeper integration among the member countries, significantly reduce the gaps between the ASEAN member states, and achieve substantial increases in their rates of economic growth. New synthesising perspectives on institutional, human capital, and productivity enhancement-related disparities and challenges of the ASEAN economies in meeting those goals are therefore useful.

In the study described in this paper, we examined empirical data from 2007 to 2017 to identify connections between research and development (R&D)-relevant human capital and productivity-enhancing factors in nine ASEAN countries, namely, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. In addition, we sought to gain an understanding of how productivity-enhancing institutional factors are associated with current levels of R&D-relevant human capital. For this purpose, we used multiple sources of data and applied the canonical correlation method. Canonical correlation, unlike the classical regression method, permits the investigation of dimensions between different sets of productivity-enhancing factors and human capital.

Section Two of this paper provides the conceptual background, and Section Three outlines the data and methodology used. Section Four presents the results of the analysis and a discussion of these results, and the last section concludes the paper.

Literature

The shift of focus from physical capital accumulation to labour and intangible factors as sources of economic growth in twentieth-century economics has paved the way for a deeper understanding of development and income inequalities across countries (Funke and Strulik 2000; Galor and Moav 2004). Theoretical foundations of this study depart largely from endogenous growth theory (e.g. Aghion *et al.* 1998; Nelson and Phelps 1966; Romer 1990), emphasising the crucial role of human capital in contributing to R&D or adoption of new technologies for the achievement of economic growth. Both the accumulated level and development of human capital are key in absorbing technological advancements and augmenting them for subsequent innovative activities, which in turn trigger returns to education (e.g. Galor and Moav 2004; Lucas 1990; Romer 1990). Theoretical advances over the past few decades include explaining factors that support human capital development, like the social environment of education (Lucas 2015), and distinguishing the quantity and quality of education (e.g. Griliches 1997). Cosar

[2]Available at: https://www.imf.org/en/Publications/WEO/weo-database/

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(2011), however, argued that because a labour force with heterogeneous skills performs different tasks, labour cannot be aggregated into a single human capital component. His theoretical argumentation showed that skilled labour availability may have even greater effects on development than have been found to date by aggregating the human capital component. On the other hand, concepts of skills mismatch (e.g. McGuinness *et al.* 2018) have provided useful insights into imperfections on how the skills of labour are matched to those required in the economy and by available technology, including digital solutions and information. Overall, given the multifaceted role that human capital has been theoretically shown to have in triggering or hindering economic development, in this study we addressed various aspects of human capital development, like quantity and quality of education, returns to education, availability of top knowledge in the economy, and technology–skills mismatch.

Advancements in endogenous growth theory have suggested that productivity enhancement induces capital intensive economic development by absorbing contemporary technologies rather than just by accumulating human capital (Aghion and Howitt 1992; Galor and Moav 2004). Departing from the Schumpeterian concepts of creative destruction and evolutionary patterns in economic development (Schumpeter 1942), production efficiency is not infinitely diminishing, and industry-heavy economies eventually tend to support development by shifting towards more intangible values and innovation that require greater development of human capital (Aghion and Howitt 1992; Galor and Moav 2004; Sokoloff 1988). Evolutionary approaches to understanding dynamics in productivity and economic development have provided important theoretical foundations for this study (for a comparative review of the endogenous growth theory with neoclassical economics foundations and evolutionary economics perspectives on development, see Verspagen 2005). On the linkages of human capital development and productivity enhancing factors, Galor and Moav (2004) and Cervellati and Sunde (2005) have provided extensive theoretical frameworks on how human capital development, technology, and innovation promote productivity growth. Furthermore, it follows from endogenous growth theory that not only does human capital trigger technological progress but also that higher levels of human capital can attract modern physical capital (Lucas 1990). Long-term growth can be achieved through absorptive capacity if, in addition to new technologies, the knowledge pool grows faster than before (Keller 1996). Similar results have been obtained empirically by Dunne and Troske (2005) and Gómez and Vargas (2012), who concluded that human capital has a larger effect on technological adoption in more technologically advanced fields of activity. In the light of the intricate theoretical insights into how productivity enhancement matters for economic development in synergy with human capital development, in this study we considered a range of factors that support productivity growth, like existing capital stock, capital inflows from outside the economy, innovation, availability of latest technologies, and real GDP on the output side as a measure of productive capacity.

However, human and physical capital accumulation alone does not account for cross-country differences in economic development and income inequalities. Institutions in standard economic theory have been often left implicit, which has raised the debate over the causal chain of institutional and human capital development (Acemoglu *et al.* 2014). There are broadly two distinct views among economists about the role of institutions in combination with human capital in fostering development. The first view follows the seminal work of Lipset (1959), who suggested that changes in human capital formation lead to the strengthening of institutions to support economic development. This view is supported by Glaser *et al.* (2014), who argued that human capital is more important than institutions at first because the accumulation of human capital eventually leads to stronger institutions and poverty can be overcome by laws and policies that support the development of human capital. Similar conclusions have been derived empirically by Guisan (2009), for example, based on a cross-country study of European countries.

The second theoretical framework, initially proposed by North and Thomas (1973), has suggested that institutions pave the way for fostering human capital accumulation that, along with physical capital and total factor productivity growth, lead to economic development. Acemoglu *et al.* (2001), for example, showed in their study that physical and human capital growth increase the output only in countries with sufficient institutional settings. Dias and Tebaldi (2012) argued that the development-inducing mechanism between productivity and human capital is self-perpetuating but requires institutions that foster human capital at first. Based on a cross-sectional empirical study, Ali *et al.* (2018) concluded that strong institutions make it possible to derive higher utility from human capital and thus promote

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growth. Overall, given the contrasting theoretical argumentations on the role of institutions in supporting development along with human capital development and the mixed empirical evidence, we incorporate in this study a set of diverse institutional measures—political stability, economic freedom, freedom to express views and preferences, and protection of property rights—to explore their nexus with human capital in fostering development.

Having established the theoretical background, we will now discuss our empirical modelling approach and available data with variables to be used as proxies in capturing the above phenomena in the ASEAN context. We have highlighted some earlier empirical studies where similar approaches were used.

Data and Methodology

In this study, we utilised multiple databases retrieved from the World Bank, Penn World Tables version 10, and the historical World Economic Forum Global Competitiveness Index for nine ASEAN countries for the years 2007 to 2017. The nine countries in the sample were Cambodia (KHM), Vietnam (VNM), Laos (LAO), Myanmar (MMR), Thailand (THA), Malaysia (MYS), Singapore (SGP), Indonesia (IDN), and the Philippines (PHL). The list of variables used in the analysis is given in Table A1 in the appendices.

Among the ASEAN member countries, Cambodia, Laos, Myanmar, and Vietnam are in the group of lower-income transition economies. There is a vast gulf between the lower-income and other ASEAN economies in their stages of development, as illustrated in Figure 1. While most of the ASEAN countries maintained a high rate of growth in GDP in constant national prices between 4.7 per cent and 5.6 per cent in the 2007–2017 period, the less developed transition economies were able to accelerate their GDP in constant national prices growth to an average rate of between 6.6 per cent and 7.7 per cent during the same period. More than 50 per cent of the ASEAN workforce is engaged in the services sector. Over 35 per cent work in manufacturing, and over ten per cent work in agriculture. The sectoral distribution of labour varies across the ASEAN countries but with more agriculture-heavy labour markets in Myanmar, Cambodia, Laos, Vietnam, and Indonesia and a more services-based workforce in Singapore, the Philippines, Thailand, and Malaysia.[3]

The economic backgrounds and historical development of the ASEAN countries are very heterogeneous. This led us to study the nexus of R&D-relevant human capital, productivity-enhancing economic factors, and productivity-relevant institutional factors in those countries. In particular, we sought to investigate how R&D-promoting human capital is associated with productivity-enhancing economic and institutional factors and where each of the nine countries is positioned with respect to these factors.

The selection of variables used in this study relied on the framework of previous theoretical studies discussed previously in Section 2. We characterised the countries' knowledge bases using tertiary education enrolment (to capture population attainment in higher or vocational education), education quality, Human Capital Index, availability of scientists and engineers (to capture the share of the top knowledge in the country), and proportion of the population using the internet (as a proxy for the accessibility of information and data) (with reference to Ali *et al.* 2018; Barro 2001; Cervellati and Sunde 2005; Galor and Moav 2004; Lee *et al.* 2010; Maneejuk and Yamaka 2021).

The advancement in productivity-enhancing economic factors stems from the initial knowledge base for utilising new technologies, attracting physical capital foreign direct investments (FDI), and innovation itself (e.g. Dakhli and De Clercq 2004; Danquah and Amankwah-Amoah 2017). The set of productivity-enhancing factors included capital stock, foreign direct investment inflows, the output side of real GDP, an innovation index, and the availability of the latest technologies. These variables capture each country's level of wealth through economic activity, capital inflows from foreign direct investments, and the overall level of real capital stock required from the physical capital accumulation side to carry out innovation (with reference to Alguacil *et al.* 2008; Dunning 1994; Fu *et al.* 2011; Iamsiraroj and Ulubaşoğlu 2015). The level of availability of the latest technologies serves as a proxy for the existing base of technologies required for innovation (Rivera-Batiz and Romer 1991; Romer 1990).

To characterise the productivity-enhancing institutional setting, we used data on economic freedom, political stability, voice accountability, and intellectual property protections. Economic freedom

[3]https://www.aseanstats.org/wp-content/uploads/2021/12/ASEAN-KEY-FIGURES-2021-FINAL-1.pdf

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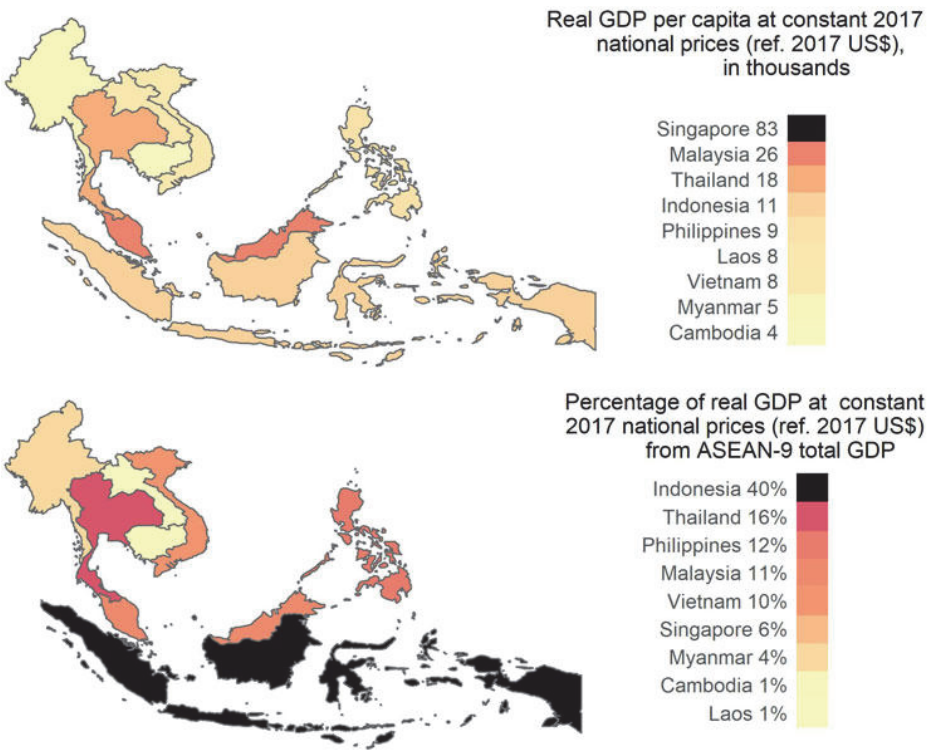

Figure 1. GDP per capita in constant national prices among ASEAN-9 countries and their contributions to total ASEAN-9 aggregated GDP in constant national prices (2017).
Source: Authors' illustration based on Penn World Tables version 10 (2019 data).

encompasses four pillars of the economic environment: government size, regulatory efficiency, openness, and the rule of law necessary to protect individuals' rights to do business freely and benefit from open markets for the flow of knowledge (see Romer 1990). Intellectual property protection, political stability, and voice accountability reflect the legal rights of inventors to protect their inventions from imitation (Guisan 2009; Hall *et al.* 2010; Lin *et al.* 2010; Xu *et al.* 2016; Yang and Maskus 2001).

Descriptive statistics are given in Table A2, and the correlation matrix is provided in Figure A1 in the appendices. Figure 2 below illustrates that the economies with higher levels of innovativeness and technology adoption have accumulated more human capital and are freer in international trade. The lower-income transition economies (i.e. Myanmar, Laos, Vietnam, and Cambodia) have long been closed economies with relatively little economic integration outside Asia, and they exhibit significantly lower levels of innovativeness. Myanmar, as a very dramatic example, was in economic isolation until 2010 because of its military regime and political issues. Innovativeness in the ASEAN countries ranges from the world-leading Singapore to the technologically underdeveloped Myanmar and Cambodia.

We used canonical correlation analysis as our main method of analysis to assess the associations between the factors of interest. Canonical correlation is a family of multivariate statistics methods that makes it possible to assess linear relationships between dependent and independent sets of variables Y and X, respectively. Canonical correlation is useful in understanding the relationship between paired sets of variables when the sample size is insufficient in terms of the desired dimensionality. This allows for a better assessment of the relationship between the sets in higher dimensions than is possible with regression analysis methods. The pairs of canonical covariates are defined as:

$$A_i = a_1 V_1 + \ldots + A_i V_i \text{ and } B_i = b_1 V_1 + \ldots + b_1 V_i, \quad (1)$$

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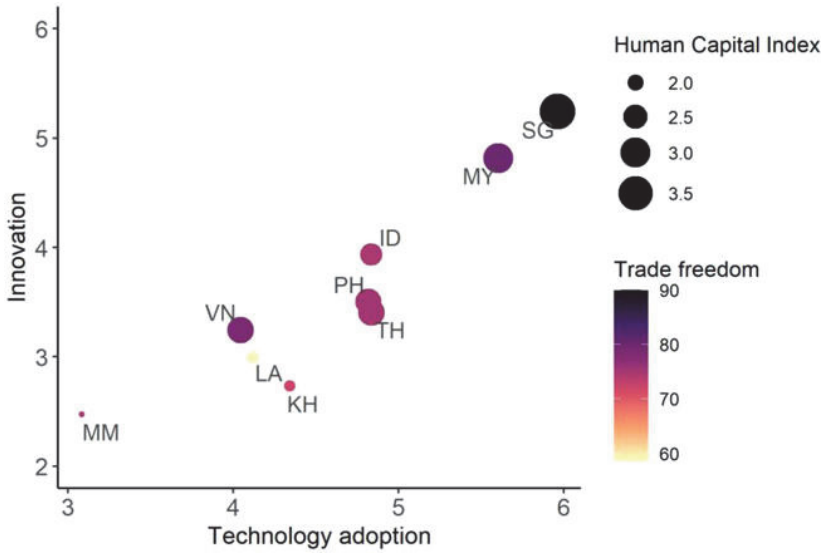

Figure 2. Adoption of technology, innovation, freedom of international trade, and human capital in ASEAN countries.
Source: Authors' calculation based on Penn World Table (PWT) 10, World Bank, and World Economic Forum Global Competitiveness Index report for 2015.

where i is the number of predictors in a multivariate set. The canonical correlation between the canonical pairs is then defined as:

$$\rho = (cov(A_i B_i))/\sqrt{(var(A_i)var(B_i))}. \quad (2)$$

To evaluate the fit of canonical correlation results, we estimated Wilks' lambda using an F-approximation for which the null hypothesis was that the canonical pairs were not correlated (Androniceanu *et al.* 2020; Hardoon *et al.* 2004; Uurtio *et al.* 2017).

The choice of method for the analysis has to suit the aim of the paper and the availability and structure of the data. Institutional change is mostly evolutionary and slow in time, and most of the variation in data stems from cross-country differences in their institutional settings and realities. Low time variation in institutional variables is a challenge for time-series estimators that require high time variability, such as vector autoregressive models or long time series such as cointegration methods. Also, many institutional variables are not measurable on a continuous scale and are not linear, which is another reason why the linear time series or cross-sectional estimators may not be an optimal choice. Canonical correlation is a helpful tool for pursuing multivariate statistical analysis; the method joins multiple variables into more general synthetic dimensions carrying a latent common meaning, finds the pairs of these synthetic dimensions that have the strongest correlation between them, and ranks these pairs according to their strength in the underlying correlation. Using canonical correlation analysis on a sample of 27 European countries for the period 2016–2018, Androniceanu *et al.* (2020) investigated the multivariate relationships between competitiveness and innovation. Our analysis explores nine ASEAN countries over an observation period of ten years at most, whereas for certain sample countries, the series are substantially shorter. Since canonical correlation relies more on data dimensionality than on data dynamics, it enables us to discover general patterns governing the institution–development nexus across the ASEAN region without being compromised by the data limitations.

Results and Discussion

The canonical correlation results for the productivity-enhancing factors and R&D-relevant human capital are summarised in Table 1 and Figure 3 below. The overall correlation between the sets of variables in the

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Table 1. Canonical correlation coefficients for the quality of human capital relevant for R&D and factors enhancing productivity

	Dimension I	Dimension II	Dimension III	Dimension IV	Dimension V
Quality of human capital relevant for R&D					
Availability of scientists and engineers	0.068	0.158	0.175	0.117	−0.109
Human Capital Index	−0.049	−0.280	0.130	−0.611	0.172
Tertiary education enrolment	0.001	0.005	−0.006	0.003	−0.007
Individuals using internet	0.001	−0.004	0.000	0.008	−0.003
Education quality	0.058	0.022	−0.096	−0.038	0.195
Productivity-enhancing factors					
Capital stock	0.000	0.000	0.000	0.000	0.000
FDI inflows	−0.002	0.005	−0.017	−0.006	−0.015
Output-side real GDP	0.000	0.000	0.000	0.000	0.000
Innovation	0.126	−0.088	0.138	0.208	−0.046
Availability of latest technologies	0.019	0.052	−0.095	−0.189	0.114
Correlation	0.986	0.780	0.526	0.493	0.138
Wilks' lambda using *F*-approximation (Rao's *F*)					
	Wilks' lambda	***F*-statistic**	**DF1**	**DF2**	***P*-value**
1 to 5	0.006	33.456	25	280	0.000
2 to 5	0.211	9.676	16	233	0.000
3 to 5	0.537	6.062	9	188	0.000
4 to 5	0.743	6.247	4	156	0.000
5 to 5	0.981	1.540	1	79	0.218

Notes: Canonical correlations coefficients are derived based on data for the years 2007–2017, except for Myanmar, for which data were only available for the years 2014–2016, and Lao PDR, for which data were only available for the years 2013–2017.
Source: Authors' calculations based on data from the World Bank, Penn World Table 10, and the World Economic Forum Global Competitiveness Index.

canonical correlation was 0.986, with a *p*-value of 0.000. The overall correlation between the sets of variables decreased considerably in the subsequent dimensions of the canonical correlation, but the correlation remained statistically significant up to the fourth dimension. The coefficients of the canonical correlation combined with the yearly weighted average of the first-dimension canonical correlation coefficients illustrated in Figure 3 indicate that although ASEAN countries with higher GDPs in constant national prices (see Figure 1 for reference) have a higher correlation between the levels of productivity-enhancing factors and R&D-relevant human capital, the overall dependency on human capital in the sample ASEAN countries is relatively low. This can be explained by the fact that a considerable number of ASEAN countries are agricultural and basic industry intensive, with little value added in production (Booth 2016; Kea *et al.* 2016). In these countries, the share of innovative firms is relatively low, and the innovative activities target mostly process improvements in order to achieve efficiency gains rather than focus on R&D-driven innovation output (see Cirera *et al.* (2021) for an extensive overview). The negative coefficient for FDI inflows indicates that FDI is not determined by the human capital-driven competitiveness of these economies but rather by the supply of cheap labour that is attractive for foreign investors looking to benefit from the possibility of cheap production.

One potential explanation for the differences in these linkages between the four ASEAN transition economies, as illustrated in Figure 3, could be that as foreign investors are looking for alternatives to China, Vietnam has proven itself an attractive destination for FDI. Foreign investors' attraction to Vietnam, which is the closest of the four transition economies to China both geographically and

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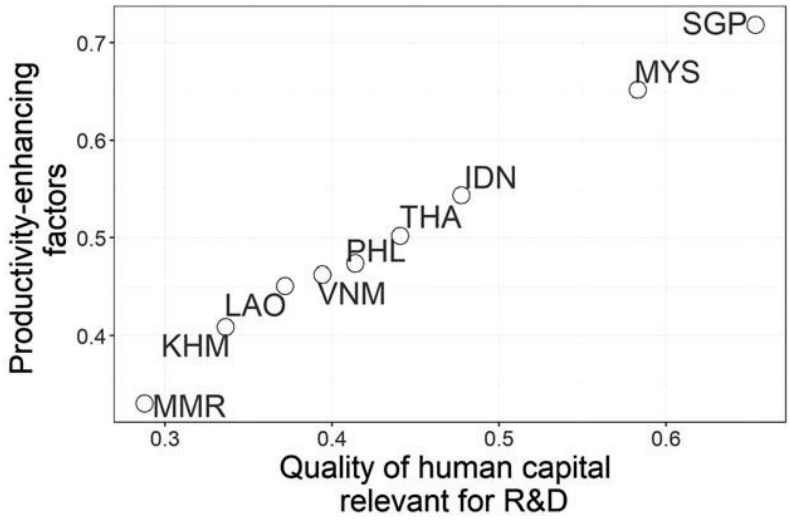

Figure 3. First-dimension canonical correlation coefficients of human capital relevant for R&D and factors in productivity growth in nine ASEAN countries.
Notes: First-dimension canonical correlation yearly weighted average coefficients were derived based on data for the years 2007–2017, except for Myanmar, for which data were only available for the years 2014–2016 and Lao PDR, for which data were only available for the years 2013–2017.
Source: Authors' calculations based on data from the World Bank, Penn World Table 10, and the World Economic Forum Global Competitiveness Index.

culturally, lies particularly in the still-unused potential of the domestic market, the abundant working-age population, and the low cost of labour, even though the level of productivity is higher than in Laos, Cambodia, and Myanmar, the other three ASEAN transition countries. In addition, Vietnam has introduced several policies to support investment and provide a better institutional framework for enhanced FDI inflows. Although Cambodia, Laos, and Myanmar are playing growing roles as target countries for foreign investors, FDI inflows to them remain modest when compared to those going to the other ASEAN countries that have higher levels of technological readiness, such as Malaysia, Thailand, and Singapore.

On the other hand, the six more highly developed ASEAN countries show a greater dependency on the human capital relevant for R&D in the factors that enhance productivity. This may be partly because manufacturing sectors with higher value added account for a larger share of these economies, and the service sector accounts for a growing share. In addition, efforts by these countries to keep pace with global demands for the availability of skilled labour encourages them to support advances in the adoption of technology and in innovation. In Singapore, which has the highest indicators for human capital relevant for R&D among the ASEAN group, a large proportion of the economic activities that occur are directly or indirectly related to advanced technology and innovation.

Next, we examine the results of our analysis of factors affecting human capital development. In the sample countries, as illustrated in Figure 4, the accumulation of human capital is correlated most strongly with the quality of education and access to tertiary education. A high degree of correlation between the urban population and internet access demonstrates the larger shares of knowledge capital in more developed and urbanised economies with better information and communications technologies, which enable better information sharing. For example, Singapore, which stands out among the sample countries in this respect, has substantially upgraded its educational system over a long time, putting considerable effort into the quality of education. As the main language of instruction is English, and children are already speaking English before they start primary school, the labour force is better prepared to access and contribute to international knowledge and communication. The quality of higher education in Singapore is widely recognised around the world, and higher education has been the most commonly achieved educational attainment level over the past five decades for the people of Singapore. The preference for higher

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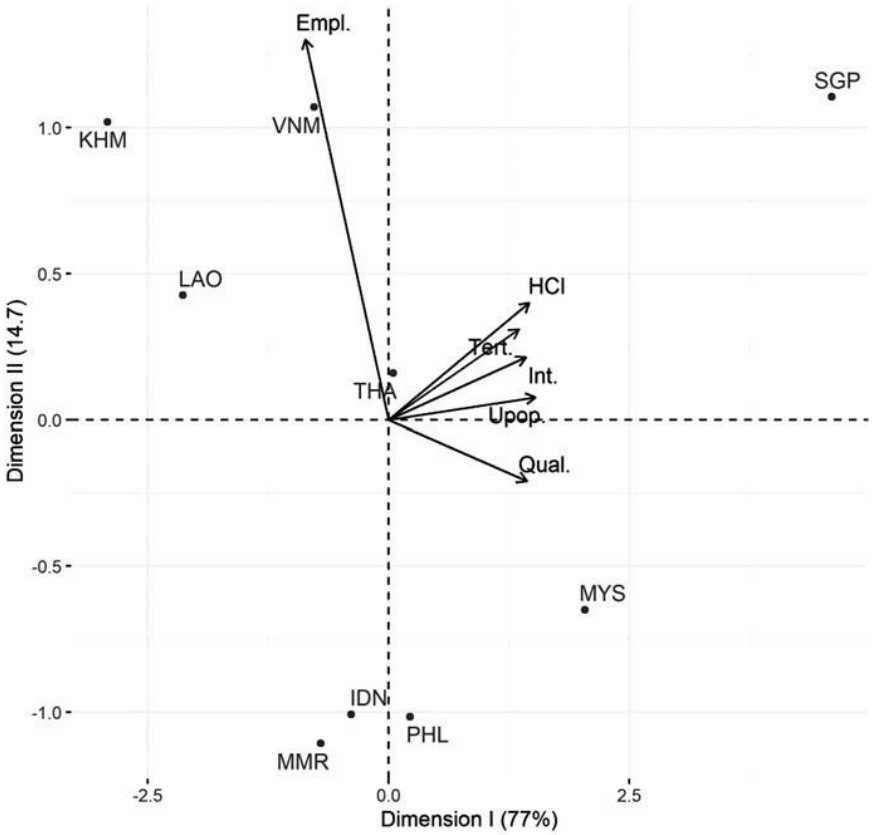

Figure 4. Principal component analysis of human capital development.
Notes: First- and second-dimension principal components were derived based on 2016 data. Abbreviations stand for the following variables: Empl. – employment-to-population ratio, 15+ total (%); HCI – Human Capital Index; Tert. – tertiary education enrolment; Int. – individuals using internet; Upop. – urban population (%), Qual. – education quality.
Source: Authors' calculations based on data from the World Bank and the World Economic Forum Global Competitiveness Index.

education has, however, left Singapore with a shortage of labour with vocational training, which has been revived recently. Other countries in the region have undertaken reforms of their education systems to respond to their development priorities and the requirements for specific skills in the economy. Although schooling attainment has considerably risen over time in the catching-up ASEAN countries, meaning a rise in quantities school enrolments, but not necessarily in quality which builds over time (Hanushek 2013).

The associations between the R&D-relevant human capital and productivity-enhancing institutional factors are summarised in Table 2 and Figure 5 below. The results show that the institutional quality in the sample countries is linked to human capital development. Compared to the results for the R&D-relevant human capital factors and productivity-enhancing factors, the canonical correlation coefficients are higher, and the overall correlation score in the first dimension is 0.978, with a *p*-value of 0.000. Again, the correlation falls in the subsequent dimensions but remains statistically significant throughout all the canonical correlation dimensions.

Institutional efficiency appears to come together with the level of human capital development. From the human capital development perspective, the overall development path in ASEAN appears to be one of producing workers with top-level skills, such as scientists and engineers, and making improvements in overall educational quality. The overall accessibility of education remains low in some ASEAN countries, however, leading to wide gaps in human capital development between them.

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Table 2. Canonical correlation coefficients for the quality of human capital relevant for R&D and productivity-enhancing institutional factors

	Dimension I	Dimension II	Dimension III	Dimension IV	Dimension V
Quality of human capital relevant for R&D					
Availability of scientists and engineers	0.022	−0.002	−0.004	−0.291	−0.021
Human Capital Index	−0.101	0.355	−0.248	0.359	0.417
Tertiary education enrolment	0.003	−0.008	−0.004	−0.002	−0.005
Individuals using internet	0.001	−0.006	0.007	−0.003	0.001
Education quality	0.074	0.130	0.021	0.133	−0.110
Productivity-enhancing institutional factors					
Political stability	−0.008	0.101	0.083	0.236	
Voice accountability	0.003	0.254	−0.059	0.200	
Economic freedom	0.003	−0.016	−0.011	0.007	
Intellectual property protections	0.068	0.038	0.089	−0.235	
Correlation	0.974	0.693	0.610	0.141	
Wilks' lambda using *F*-approximation (Rao's *F*)					
	Wilks' lambda	***F*-statistic**	**DF1**	**DF2**	***P*-value**
1 to 5	0.016	31.141	20	253	0.000
2 to 5	0.320	9.162	12	204	0.000
3 to 5	0.615	7.147	6	156	0.000
4 to 5	0.980	0.806	2	79	0.450

Notes: Canonical correlation coefficients were derived from data for the years 2007–2017, except for Myanmar, for which data were only available for the years 2014–2016, and Lao PDR, for which data were only available for the years 2013–2017.
Source: Authors' calculations based on data from the World Bank, Penn World Table 10, World Bank Governance Index, and the World Economic Forum Global Competitiveness Index.

The greatest concern regarding human capital development is in the transition economies—Cambodia, Laos, Myanmar, and Vietnam—where the share of the population that is rural is higher than it is in the more advanced ASEAN countries and the educational opportunities for the urban and rural populations are unequal. Another issue with the accumulation of human capital in all four of the transition economies in the ASEAN group is their high level of dependency on economic activities with low value added that do not necessarily require high levels of education but rather depend on simple skills that can be acquired on the job. As argued by Galor and Moav (2004) and Cervellati and Sunde (2005), acquiring education is costly and relies on often short-term rational considerations about the benefits gained from the higher level of knowledge and the skills accumulated in view of the income lost during the same period. The limited opportunities and perspectives for exploiting the benefits of more advanced education in the less developed ASEAN economies tend to adjust the values of educational needs among the population. Furthermore, even in the developed economies of the ASEAN group, technological disruptions, such as developments in robotics and machine learning, have replaced specific tasks in existing jobs, and this has led to changes in demand for skills in several occupations. The new trends require not only the developing economies of ASEAN but also its more developed ones to carry out educational reforms to meet current labour needs and anticipate future economic demands.

Conclusion

This paper has described a study of the links between the quality of human capital, productivity-enhancing factors, and institutional backgrounds in nine ASEAN countries based on data for the period

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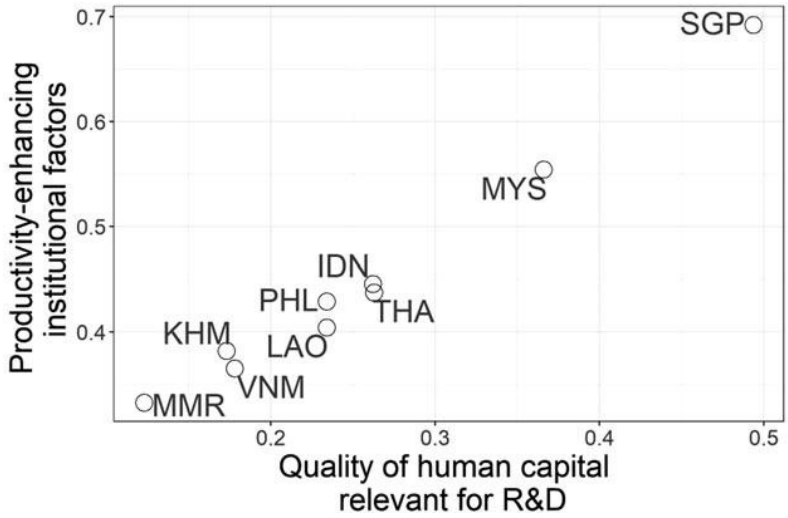

Figure 5. First-dimension canonical correlation coefficients of the quality of human capital relevant for R&D and institutional factors by country.

Notes: First-dimension canonical correlation yearly weighted average coefficients were derived from data for the years 2007–2017, except for Myanmar, for which data were only available for the years 2014–2016, and Lao PDR, for which data were only available for the years 2013–2017.

Source: Authors' calculations based on data from the World Bank, Penn World Table 10, World Bank Governance Index, and the World Economic Forum Global Competitiveness Index.

2007–2017. The sample countries are notable for the heterogeneity of their institutional backgrounds and of their adoption of technology and innovation. Countries with high GDP per capita in constant national prices, such as Singapore and Malaysia, exhibit a high association between R&D-relevant human capital development, productivity-enhancing factors, and institutional strength. These findings are consistent with previous studies that have argued that human capital is indispensable for attracting FDI, adopting new technologies, innovating, and achieving economic growth (e.g. Cervellati and Sunde 2005; Che and Zhang 2018; Dakhli and De Clercq 2004; Danquah and Amankwah-Amoah 2017; Dunne and Troske 2015; Galor and Moav 2004; Gómez and Vargas 2012; Keller 1996; Lucas 1990). In addition, human capital is indispensable for institutional development, as stressed by Glaser *et al.* (2014) and Ali *et al.* (2018).

The four transition countries in the ASEAN group—Laos, Cambodia, Vietnam, and Myanmar—are the fastest growing in the region, but they are still heavily dependent on the accumulation of physical capital in the low value-added agricultural and production sectors, where there is quite a low level of technology adoption and even less innovation. Cambodia, Laos, and Myanmar have remained closed economies, with institutional backgrounds that are largely focused on state control and a low level of human capital development. The other ASEAN countries have advanced faster technologically, which is reflected in their higher levels of income and their productivity-enhancing factors.

Although technology adoption and innovation have been understood in the ASEAN countries to play important roles in achieving long-term sustainable growth and overcoming poverty gaps, the levels of human capital needed to achieve these goals are yet to be developed in the transition economies of the ASEAN group or even in the more developed countries in the group. These developments appear to be asymmetric in time and associated with the countries' institutional backgrounds. Thus, the main policy implication stemming from the results of this research points towards the need for human capital accumulation, especially concerning the educational quality and availability of a workforce with top-level skills. Knowledge accumulation is crucial for adopting new technologies that create a sufficient technological base for innovation, institutional development, and subsequent economic growth.

A key issue for human capital in the ASEAN countries is that the institutional setting appears to be rather elite oriented, as opportunities for human capital development are unequally distributed between countries. The more developed ASEAN countries are more focused on developing top-level skills, having

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managed to achieve relatively high levels of human capital development, but the transition economies of the ASEAN group are lagging behind. Human capital endowments remain low for these countries, and access to training may be biased towards urban areas, leaving a large part of the population with few opportunities for education and training.

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APPENDICES

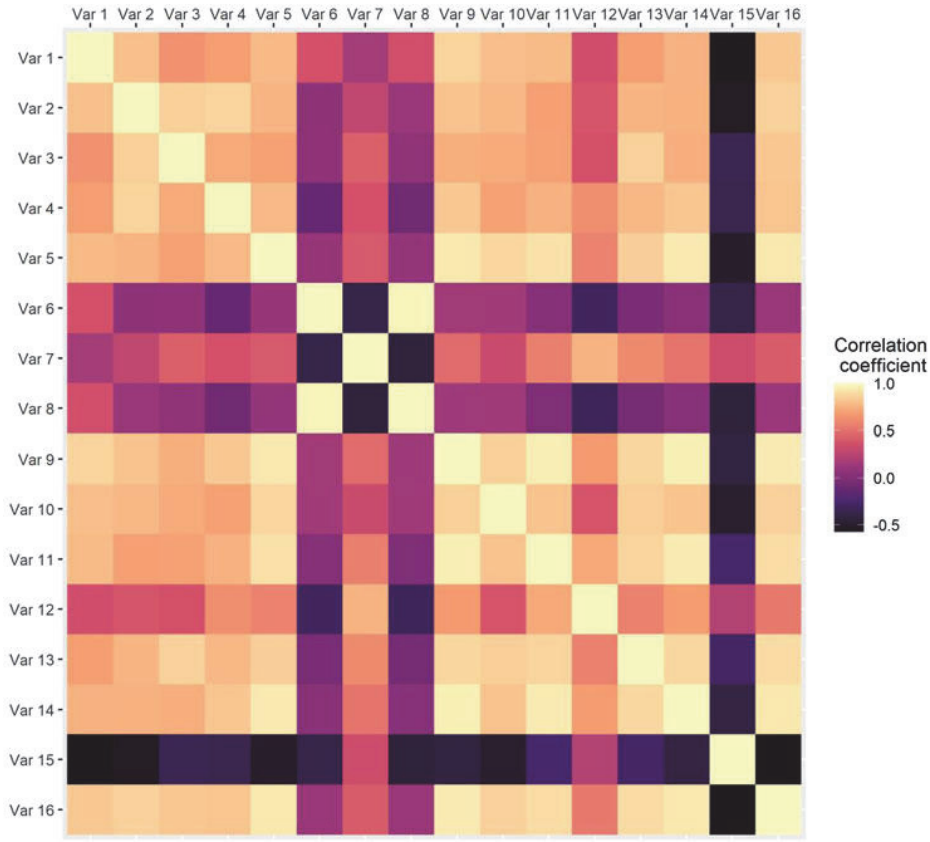

Figure A1. Correlation matrix.
Notes: Variables have been relabelled to save space. Variable order corresponds to the order shown in Table A1 and Table A2.
Source: Authors' calculations based on the World Bank TC360 data, World Bank Governance Indicators, Penn World Table 10.0, and World Economic Forum Global Competitiveness Index data for ASEAN-9 countries for the years 2007–2017.

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Table A1. List of variables

	Description	Type	Source
	Human capital relevant for R&D		
Availability of scientists and engineers	Availability of scientists and engineers index, value is between one and seven, where higher values indicate higher availability	Continuous	World Economic Forum Global Competitiveness Index
Human Capital Index	Human Capital Index, based on years of schooling and returns to education	Continuous	Penn World Tables 10.0
Tertiary education enrolment	Tertiary education enrolment, gross per cent	Percentage	World Economic Forum Global Competitiveness Index
Individuals using internet	Percentage of individuals using internet from total population	Percentage	World Economic Forum Global Competitiveness Index
Education quality	Quality of education index	Continuous	World Economic Forum Global Competitiveness Index
	Productivity-enhancing factors		
Capital stock	Capital stock at constant 2017 national prices (in mil. 2017 US$)		Penn World Tables 10.0
FDI inflows	Foreign direct investment, net inflows (percentage of GDP)	Percentage	World Bank TC360 data
Output-side real GDP	Output-side real GDP at chained PPPs (in mil. 2017 US$)		Penn World Tables 10.0
Innovation	Aggregate innovation index	Continuous	World Economic Forum Global Competitiveness Index
Availability of latest technologies	Availability of latest technologies index, value is between one and seven, where higher value indicates better availability of modern technologies	Continuous	World Economic Forum Global Competitiveness Index
	Productivity-enhancing institutional factors		
Voice accountability	Index that captures freedom to express ideas and preferences while having the security to do so	Continuous	World Bank Governance Indicators
Political stability	Index that captures perceptions of the government stability and absence of unconstitutional or violent means	Continuous	World Bank Governance Indicators
Economic freedom	Index that captures perceptions of economic freedom and policy control.	Continuous	World Bank TC360 data
Intellectual property protections	Index of intellectual property rights, value is between one and seven, where higher value indicates higher protection of intellectual properties	Continuous	World Economic Forum Global Competitiveness Index

(*Continued*)

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Table A1. (*Continued.*)

	Description	Type	Source
	Population characteristics		
Employment-to-population ratio, 15+ total (%)	Employment percentage of working-age population.	Per cent	World Bank TC360 data
Urban population	Percentage of population living in urban areas.	Per cent	World Bank TC360 data

Table A2. Descriptive statistics

Variable	Mean	*SD*	Min	Max	*N*
	Human capital relevant for R&D				
Availability of scientists and engineers	4.20	0.74	2.82	5.39	85
Human Capital Index	2.52	0.50	1.65	3.97	85
Tertiary education enrolment	31.78	19.78	2.91	92.20	85
Individuals using internet	32.06	24.97	0.28	82.10	85
Education quality	4.19	0.94	2.55	6.22	85
	Productivity-enhancing factors				
Capital stock	3187470.87	3805787.40	77793.59	15823088.00	85
FDI inflows	6.71	6.54	0.06	29.35	85
Output-side real GDP	713964.41	693274.78	31562.12	2816072.25	85
Innovation	3.63	0.81	2.24	5.39	85
Availability of latest technologies	4.83	0.87	2.52	6.32	85
	Productivity-enhancing institutional factors				
Government efficiency	3.97	0.92	2.67	6.05	85
Political stability	−0.24	0.86	−1.78	1.62	85
Economic freedom	61.91	11.73	39.20	89.40	85
Intellectual property protections	3.89	1.14	2.46	6.28	85
	Population characteristics				
Employment-to-population ratio, 15+ total (%)	68.83	7.76	58.15	85.37	85
Urban population	50.51	24.18	19.41	100.00	85

Source: Authors' calculations based on the World Bank TC360 data, World Bank Governance Indicators, Penn World Table 10.0, and World Economic Forum Global Competitiveness Index data for ASEAN-9 countries for the years 2007–2017.

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Appendix 2

INSTITUTIONS AND THE R&D ENGAGEMENT OF SMES IN LAOS

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Institutions and R&D engagement of SMEs in Laos

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ABSTRACT

We investigate the association between research and development (R&D) engagement by small and medium enterprises (SMEs) and the institutional environment in Laos. We employed multivariate imputation by chained equations and full Bayesian inference to analyse data from the 2016 and 2018 World Bank Enterprise Surveys for Laos. Our findings show that Lao SMEs that engage in R&D are likely to experience more frequent tax inspections and more solicitation of bribes by government authorities, than Lao SMEs that do not engage in R&D. Firms that perceive political uncertainty as an obstacle to doing business are 28% less likely to engage in R&D activities. These findings raise concerns about the effectiveness of institutions in supporting intellectual property rights in Laos, and have policy implications for promoting productivity of small and medium-sized firms.

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Introduction

Innovation plays an essential role in enhancing productivity (Aghion & Howitt, 1992; G. M. Grossman & E. Helpman, 1991; Jones, 1995; P. M. Romer, 1986; P. Romer, 1990). The endogenous growth theory literature has linked economic growth and development with innovation and technological progress, which induces subsequent productivity gains (Abramovitz, 1993; Coe & Helpman, 1995; Funke & Strulik, 2000; G. M. Grossman & E. Helpman, 1991; Jones, 1995; P. M. Romer, 1986). Although numerous streams of the literature have identified various factors that hamper R&D investments and the subsequent emergence of innovation, more recent studies of R&D and innovation systems have concluded that a country's institutional setting is one of the main determinants of cross-country differences in R&D, innovation, and growth (Acemoglu & Johnson, 2005; Acemoglu et al., 2001; Barro, 1990; Johnson et al., 2002; Lin et al., 2010).

Numerous studies have linked the institutional setting in a country with firm-level innovation or research and development (R&D) engagement. However, less attention has been paid to small and medium-sized enterprises (SMEs) and the general perception of a country's institutional setting in the context of developing economies,[1,2] Promoting innovation incentives among SMEs is important for economic development, as SMEs

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make up most of the businesses around the world and account for nearly half of all employment.[3] Ayyagari et al. (2007) explained that more developed economies have higher-density SME sectors with higher contributions to overall employment. The SME sector does not shrink as a country's economy develops but rather grows with it, which suggests that the economic importance of SMEs is not likely to decrease. Creating niche markets is also crucially important for SMEs to sustain their competitive positions and survive market fluctuations. Thus, SMEs play an important role in the formation of a business environment that supports socioeconomic development, especially for less developed countries with more volatile economies (Tambunan, 2008).

This article describes an investigation of the association between SMEs' R&D engagement and the SMEs' self-perceived institutional setting in the Lao People's Democratic Republic. The perception of the institutional setting was observed from three perspectives: (i) political uncertainty, (ii) bribe solicitation by the government, and (iii) frequent tax inspections by the government. The interest in studying Lao firms' R&D engagement arises from efforts by the government of Laos since the early 2000s to promote SMEs' productivity by improving the country's legal and regulatory frameworks. For example, Laos has introduced a progressive lump-sum tax for SMEs that is intended to make the tax burden more transparent and simple for SMEs in Laos.[4] Laos has also introduced numerous changes to intellectual property rights laws that are intended to strengthen property rights. However, regulatory changes may bring along increased uncertainty about the institutional environment and the imposed regulations may not be effective. Little is known how the actual implementation of regulatory measures and overall political uncertainty are perceived by R&D-focussed SMEs in Laos. What we know so far is that regardless of these regulatory changes, however, the economic growth of Laos still stems mainly from energy, mineral extraction and mining, and low value-added agriculture, and industry.[5]

In this study, we employed a repeated cross-sectional dataset from the 2016 and 2018 World Bank Enterprises Surveys for Laos, representing 614 small and medium enterprises. We estimated the statistical association between the firms' institutional setting perceptions and their willingness to invest in R&D. To address reporting bias and incidental parameters associated with the availability of mainly binary and ordinal explanatory variables and intercorrelated dependent variables, we applied multivariate imputation by chained equations and full Bayesian inference logistic regression with a Bernoulli distribution.

The main results of this study indicate that regardless of efforts to improve the regulatory system and property rights protection in Laos, firms that invest in R&D have a significant likelihood of experiencing government exploitation through bribery. The results also reveal that tax inspections are more likely for firms that engage in R&D. Moreover, perceived political uncertainty is negatively associated with the probability of the firm investing in R&D. In other words, firms that consider R&D investments may be discouraged by an institutional environment characterised by high political uncertainty which brings along higher risks for the returns on their investments.

The article proceeds as follows. The next section provides an overview of previous findings from the literature on how the apprehension of some key aspects of institutional effectiveness and political uncertainty affect firms' R&D investment activity. The third section describes the dataset used, and the fourth section presents the empirical analysis approach used. The fifth section discusses the results and presents conclusions drawn from the main findings.

Literature review

Inequality in wealth distributions has given rise to numerous discussions on why the rich economies are rich, and why the poor have remained poor (see, for example, Alfaro et al., 2008; Hibbs & Olsson, 2004; Lucas, 1990; Olson, 1996; R. E. Hall & Jones, 1999). The endogenous growth theory literature has linked economic growth and development with innovation and technological progress which induce subsequent productivity gains (Abramovitz, 1993; Coe & Helpman, 1995; Funke & Strulik, 2000; G. M. Grossman & E. Helpman, 1991). In addition, investment in R&D is an indispensable and essential predeterminant for innovation and long-term growth (B. Hall & Reenen, 2000; Frenkel et al., 2001; Shefer & Frenkel, 1998).

Since the returns on R&D are highly uncertain and tend to emerge with a considerable time lag, the linkage between R&D, innovation, and subsequent productivity gains are difficult to measure (B. E. Hall & Lerner, 2010; B. H. Hall et al., 2010). Ayyagari et al. (2007) explained that more developed economies have higher-density SME sectors with higher contributions to overall employment. In addition, the SME sector increases in size with economic development, indicating that the economic importance of SMEs is likely to increase. In addition, creating niche markets is crucially important for SMEs to sustain their position in overall competition and to survive market fluctuations. Thus, SMEs play an important role in the business environment formation that eventually supports socio-economic development, which is especially important for less developed countries with more volatile economies (Tambunan, 2008).

Several studies have linked the political institutions and enforcement of property rights to a firm's investment decisions. The role of property rights in achieving economic growth was discussed by Adam Smith already in A. Smith (1776). Barro (1990) concluded that political uncertainty is a proxy for a country's property rights. Economies with high political uncertainty are often characterised by inefficient legal systems, poorly or selectively enforced property rights, and no commitments from the government (Haber et al., 2003; Svensson, 1998). Under such regulatory inefficiency, firms use their political connections to enhance operations, increase access to finance, enforce property rights and achieve favourable decisions in corporate litigations (Boubakri et al., 2013; Cumming et al., 2016; Xu et al., 2016). Lin et al. (2010), Xu et al. (2016), and Cumming et al. (2016) have studied how political uncertainty affects Chinese firms' investment decisions. China, like Lao PDR, is a single-party communist state that is politically rather stable on higher levels of political power.[67] In such a centralised setting, (local) government officials are among the most important public sector counterparts for firms. With a change in some government officials or entire local leadership, interpretation and implementation of policies and practices may change as well, resulting in increased apprehension of political uncertainty (Cumming et al., 2016). Given this, Xu et al. (2016) define political uncertainty as the shock that weakens a firm's political connections and affects investment decisions.

Studies conducted by Lin et al. (2010) and Xu et al. (2016) concluded an adverse effect of increased political uncertainty on firms' reinvestment decisions. Under political uncertainty, firms tend to reduce their cash holdings because of the increased likelihood of being exposed to 'government taking hand', i.e. bribery solicitation (Xu et al., 2016), and hinder firms' incentives to innovate (Lin et al., 2010). Cumming et al. (2016) concluded that the negative effect of political uncertainty on innovation is less severe if a firm has

connections to political party leaders that promote direct government support and access to finance.

Similarly, Johnson et al. (2002), who studied firm- and country-level profit reinvestment problems in European transition economies, found that profit reinvestment rates are negatively affected by inefficient institutional settings, and thus, countries with higher rates of corruption and poor regulations on business licencing experience lower rates of profit reinvestment among privately owned firms. Cull and Xu (2005), who conducted a similar study of 2,400 Chinese firms, argued that a positive investment climate with greater protection of firms' rights boosts firms' confidence in reinvesting profits and thus increases firms' reinvestment likelihood.

Further extensive review about intellectual property rights protection as an institutional enabler of R&D investments is provided by Rugman (1986), P. J. Smith (1999), Yang and Maskus (2001), Hausmann and Rodrik (2003), and B. H. Hall et al. (2010) among others. Protection of intellectual property rights promotes R&D by providing inventors exclusive legal rights to the use of their inventions for certain periods of time. When property protection systems fail, private returns for inventors decreases, suppressing willingness to undertake highly uncertain R&D investments (B. H. Hall et al., 2010; Rugman, 1986).

Numerous ways to measure the strength of property protections have been explored in previous research. Lin et al. (2010) analysed the effects of property protection regulations and government services' effectiveness on Chinese firms' R&D investment decisions using bivariate probit regression. They found that property rights via contract enforcement play a key role in supporting R&D investment decisions among firms, regardless of firm size. In addition, their findings showed that government services influence firms' willingness to undertake innovative activities. While large firms' R&D decisions were mostly influenced by the effectiveness of government services, smaller firms that are more credit constrained are more influenced by governments' 'helping hand' and 'taking hand'.

Using the difference-in-difference method, Brown et al. (2017) detected R&D-promoting domestic policies and institutional factors at the business sector level in 19 OECD countries. They concluded that R&D investments fall below countries' socially optimal levels[8] mainly because of the weakness in the countries' accounting standards and contract enforcement regulations. They also found that strong intellectual property (IP) protections incentivise R&D investments in the high-tech sector and that weak property protection regulations cause the social return of R&D investments to be substantially smaller.

A few studies (e.g. Anokhin & Schulze, 2009) have attempted to explain the influence of corruption on firm innovation. However, conflicting findings have been obtained on whether the effect of corruption is positive – what Lui (1985) referred to as a 'grease-the-wheels' effect – or negative – what Ades and Tella (1997) referred to as a 'sand-in-the-machine' effect. For example, using firm-level data for 48 developing and emerging countries, Paunov (2016) found that corruption decreases the probability that firms will obtain quality certificates. The link between R&D engagement and corruption is likely to depend on the overall level of corruption in the economy, so that the grease-the-wheels argument might hold under institutional environments characterised by high corruption [reference-check your other paper]. For example, using data for Vietnamese firms, Nguyen et al. (2016) showed that informal payments have a grease-the-wheels effect on innovation. This finding is explained by the fact that entrepreneurs might prefer to gain short-term

transactional benefits of corruption to overcome the burdensome procedures in business environments where institutional quality is poor. However, this tendency ignores the hidden and prolonged costs on firms and damages the broader business environment and societal development in the long term. Similarly, many studies have found a positive association between corruption and firm performance in Asian countries (see, e.g. Chen et al., 2013; Vial & Hanoteau, 2010). It is widely believed that bribery is widespread among Asian firms (Lee & Oh, 2007), and embedded corruption has been attributed to the cultural and economic structures of Asian countries. For example, Wei and Kaufmann (1999, p. 10) suggest Asian exceptionalism, such that 'corruption has been part of the Asian culture for a long time and does not seem to hamper business there'. Considering the impact of corruption on firm innovation, one can expect that bribery may have a greasing the wheel effect on firms' R&D engagements in Laos.

Firms may seek government contracts to share the sunk costs of R&D engagements and find an immediate buyer for their R&D outcomes. However, Bruce et al. (2018) pointed out that public-sector contracts are characterised by high rigidity (Moszoro et al., 2016), because of political pressure from third parties (Spiller & Moszoro, 2014) and typical bureaucratic regulations (Moe, 1990). Since the outcomes of R&D activities are uncertain and the market for technology suffers from some well-documented shortcomings (Arora & Gambardella, 2010), it could be argued that government monitoring and assessment may serve critical functions in the governance of publicly funded initiatives (Holmstrom, 1989). In a recent empirical study, Nishimura and Okamuro (2018) found that government monitoring has a positive impact on firm innovation and R&D engagements.

Data

The empirical analysis conducted in this study made use of data from the World Bank Group Enterprise Surveys conducted in 2016 and 2018, representing 614 firms operating in the Lao People's Democratic Republic. The number of Lao firms in the survey was reduced for our study sample by excluding firms with government ownership to prevent the possible effects of firms' R&D investment decisions having been driven by government agendas (in view of, e.g. Choi et al., 2011; Dewenter & Malatesta, 2001) and government-owned firms' potentially different operating environments and practices, under the specific legal framework and partially government-led economic system in Laos (see Sun et al., 2002).

We used as a dependent variable a binary R&D engagement variable (*rd*) which takes a value of one if the firm has self-reported in the survey that it has carried out R&D activities and zero otherwise. The R&D engagement variables differ for the two survey years, and thus, we used different ways to calculate our dependent variable. The 2016 World Bank Enterprise Survey had two separate survey questions about firms' R&D engagement. One question enquired whether the firm had conducted formal R&D activities during the past three years, and the second question asked how much the firm had invested in official R&D activities during the past fiscal year. The 2018 questionnaire included a binary R&D engagement variable for the past fiscal year. Thus, for the 2016 observations, we combined our binary outcome variables so that the outcome took a value of one if the firm had reported R&D expenditures during the last fiscal year and zero if the firm had reported no R&D activities during the past three years. For the year

2018 observations, we formed the outcome based on the available binary variable indicating whether the firm had engaged in any R&D activities.

We used as explanatory variables of firms' R&D engagement a set of proxies for government involvement in private sector business affairs and the power distance between the government and firms in conducting business. Following Barro (1990), Lin et al. (2010) and Xu et al. (2016), for a general apprehension of the business environment framed by the government, we used perceived political uncertainty as an obstacle for doing business (*political*). The variable *political* is an ordinal scale variable that takes values from 0 if the firm does not perceive political uncertainty as an obstacle for doing business up to 4 if political uncertainty is perceived as a severe obstacle for doing business. In addition to the overall adverse effect that political uncertainty has on the riskiness of investments, the presence of higher political uncertainty apprehension may mean that firms' assess property protections to be lower because of a higher risk of being exploited (Barro, 1990).

We incorporated as an explanatory variable bribe solicitation by the government (*bribe*), which is a binary variable indicating whether government officials have requested informal payments or gifts (bribe $= 1$) or not (*bribe* $= 0$). Furthermore, for a proxy of government intrusion into business affairs and consequent risk for investors, we used the number of tax inspections by government officials (*inspections*). In addition, a binary explanatory variable *contracts* takes a value of one if the firm has secured or sought to secure government-business contracts during the past fiscal year and zero otherwise, to identify firms whose business is dependent on transactions with the government.

We included various firm- level control variables. The firm age (*age*) was derived from the firm establishment date and was limited to 50 years. Firm size was captured through the number of full-time equivalent employees (*employees*) and annual sales revenues (*sales*). Access to credit was captured by the variable *credit*, which is an ordinal variable that takes values from 0 to 4— the more the firm perceive credit availability as a business obstacle, the higher the value of the credit constraints variable is. The effect of human capital is reflected through the ordinal *education* variable, which captures the firm's apprehension of the availability of sufficiently educated human capital as an obstacle in doing business, on a scale of 0 to 4. The less the firms perceive the availability of human capital as a constraining factor in doing business, the lower the score is. Firm ownership effects were captured by the binary variable *foreign*, which takes a value of one if more than 50% of the firm shares belong to foreign individuals and zero otherwise. We incorporated year and industry dummies in the models.

A detailed list of the variables and variable definitions used is given in Appendix A.1. Summary statistics for the variables are given in Appendix A.2. The correlation matrix is given in Appendix A.3.

Methodology

First, we addressed potential selection bias and sample size limitations related to missing responses in the survey data, as shown in the summary statistics table in Appendix A.2. According to Rubin (1976, 1978) and Graham (2009), missing responses do not pose a significant problem under the assumption that responses are observed at random and missing at random. However, this assumption is rarely plausible for responses that address sensitive or even illegal business affairs (see, e.g. Lee et al., 2010; Williams et al.,

2016), which is the case for the survey data used in our study of government – business relations. In addition, our estimations rely on a relatively small number of individual firms compared to the number of variables of interest. In the presence of a limited sample, omitting missing observations leads to a significant loss of information and may result in maximum likelihood estimates that are less concentrated and may depart from reality. To avoid omitting observations with missing data points, we used multiple imputations with chained equations[9] to impute the missing values in the explanatory variables for capturing the institutional environment and government – business relations. Binary variables such as *bribe* and *contracts* were imputed using logistic regression, the ordinal variable *political* was imputed using proportional odds, and the frequency of tax inspections (*inspections*) is imputed using predictive mean matching. Graham et al. (2007) suggested that the number of multiple imputations should be compatible with the percentage of data missing in the data frame. Pan et al. (2014) and Hershberger and Fisher (2003) found that the optimal number of imputations required is higher and may even rise to a few hundred imputations per missing value in the dataset. Seeking to maximise efficiency from the multiple imputations, we followed the advice of Hershberger and Fisher (2003) and used 300 multiple imputations with 50 iterations.

Next, we estimated firms' R&D engagement using Bayesian logistic regression with a Bernoulli distribution.[10] We used Bayesian regression for two reasons. First, the variables in our dataset are mainly binary and ordinal variables, and prior inference in Bayesian estimation enabled us to control for the possible randomness of parameter estimates and separability. Second, some of the dependent variables in our model are intercorrelated and may be endogenous to some extent. For example, R&D investing firms may experience more frequent tax inspections because of their activities, which may also lead to a higher likelihood of experiencing corruption. When the regressor is endogenous, posterior intervals become wider, and the true effect cannot be identified. Incorporating prior information does not remove potential endogeneity bias, but it does supply additional information to the model for calculating the size of the effect and the confidence intervals (see Bollinger & van Hasselt, 2017). Moreover, as the data are available in a cross-sectional setting, without additional information for firms across different time dimensions, we can only interpret the association between the outcome and regressors; we cannot interpret causality. Figure 1. below presents a simplified graphical illustration of Bayesian logistic regression with measurement error.

The logistic algorithm approximately linearises the derivative of the log-likelihood and estimates in each iteration step the latest estimate of the beta β by solving for the weighted least squares (Gelman et al., 2008; McCullagh & Nelder, 1989). During each iteration step, the logistic algorithm determines the pseudo-data z_i and inverse pseudo-variance $\left(\sigma_i^z\right)^{-2}$ from the linearised derivative of the log-likelihood (Gelman et al., 2008). The prior inference alters the estimation of the weighted least squares beta coefficients by approximating the likelihood with the existing prior distribution of estimates, resulting in the prior-augmented estimation of the beta coefficients (Gelman et al., 2008; McCullagh & Nelder, 1989). The weaker the prior information about the parameter estimate is, the more the Bayesian estimation relies on the present data for sampling the posterior distribution.

The posterior distribution is sampled using the Hamiltonian Monte Carlo (HMC) 'no-U-turn' sampler (NUTS), which is one of the Monte Carlo Markov chain (MCMC) sampling

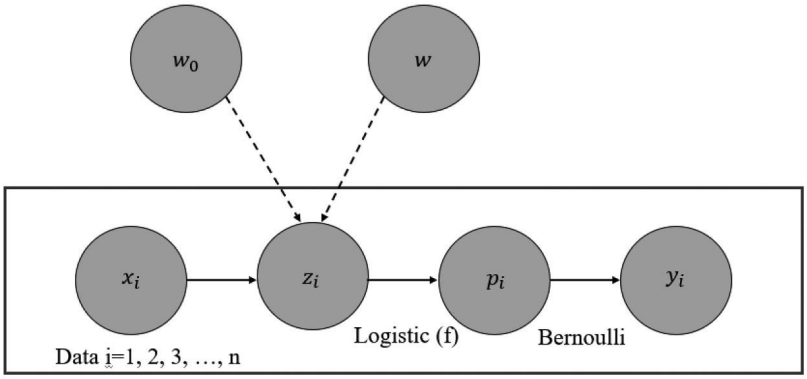


Figure 1. Simplified graphical presentation of Bayesian logistic regression with a Bernoulli distribution. Notes: x_i denotes the original information captured in the data. The prior inference is denoted by w for independent variables and w_0 for the intercept, which in a general form can be formulated mathematically as $w \sim N(\mu, \sum)$ where μ represents the prior mean and $\sum$ represents the prior standard deviation. $z_i = w^T x_i$ denotes the pseudo data, and the discriminative probabilistic linear classifier is formulated as $\Pr(y_i = 1|x_i) = \frac{1}{1+exp^{-z}} = \Lambda(z_i)$. Thus, $y_i \sim Bernoulli(p_i)$ denotes the estimated posterior distribution estimated from the exact Bayesian inference for logistic regression with a non-conjugate prior, formulated as $\Pr(y_i = 1|w^T x_i) = \int^{\Lambda}(w^T x_i)p(w)dw$. Source: compiled by authors

algorithms. HMC sampling seeks to avoid random walk behaviour of the estimates and reduce the sensitivity to correlated parameters (Hoffman & Gelman, 2014). Ishwaran (1999) explains that HMC works as a sophisticated discretisation of Hamiltonian dynamics by combining a deterministic step with a stochastic step. The HMC algorithm generates an ergodic Markov chain with an equilibrium distribution that avoids random walk behaviour of the algorithm in calculating the stationary distribution $N_K(0, I)$ of a momentum variable.

For prior inference, we estimated our datasets using mainly four different sets of priors. In the first two estimations, we applied the normal and Student's t distribution vague priors,[11] which enabled us to identify problems with the model estimations and sample the posterior distribution. In the third estimation, we rescaled the estimation following the suggestion of Gelman et al. (2008) to use a normal distribution generic prior[12] to rescale binary independent variables and a weak Student's t distribution prior[13] equivalent to the Cauchy prior that Gelman et al. (2008) proposed for rescaling all other independent variables. In the fourth estimation, we used weakly informative empirical priors based on the expected associations between dependent and independent variables derived from the previous estimation[14] and in keeping with the literature.

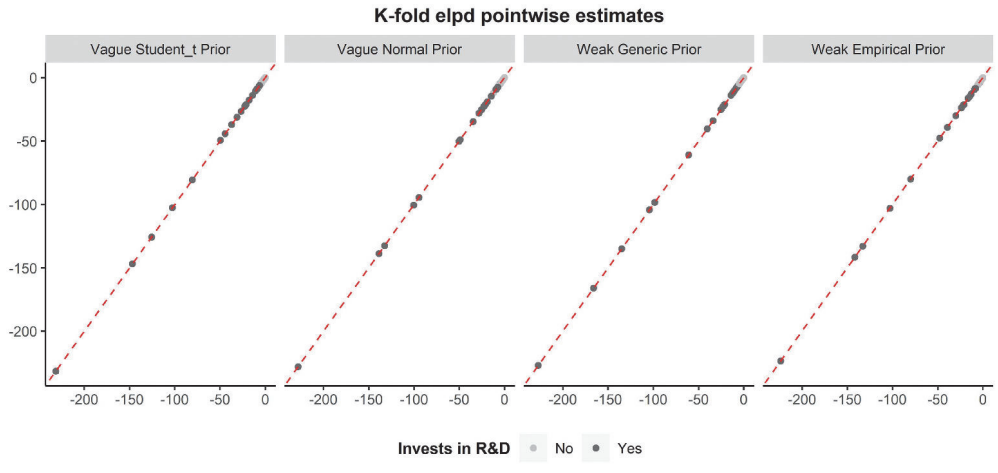
We estimated our Bayesian logistic regression with 2,000 default iterations and 1,000 burn-in iterations with four chains. To bring the estimations' sample closer to the true population characteristics, survey weights provided by the World Bank Enterprise Surveys were added to the estimation. To improve the convergence of the NUTS sampling, we increased the maximum tree depth to 15 from the initial depth of 10, and we increased the value for delta for determining the leapfrog steps for accepting the posterior draw from 0.8 to 0.99.

Empirical results

Our estimation results for different prior inferences are reported in Table 1 in terms of logistic coefficients, along with 95% confidence intervals in square brackets. The convergence of the estimates was evaluated by visual examination of density and trace plots and the estimated values of the *rhat* statistics. The reported statistics indicate that the results became more concentrated in the case of more informative prior information, as expected. The differences across estimations were rather low, however, indicating sufficient robustness of the models.

Next, the estimated models' predictive powers were compared using K-fold cross-validation with 10 folds. The best-fitting model was chosen based on the estimated expected log pointwise predictive density (ELPD) and the corresponding K-fold information criterion. The estimated ELPDs, along with the K-fold information criteria and estimated standard deviations, are presented in Figure 2, which indicates that the model with the weakly informative empirical prior has the highest predictive power. This model is therefore used as the baseline estimation for further discussion of the findings. For a more intuitive interpretation of the results, the baseline results are illustrated in Figure 3, which presents the odds ratios (OR) and average marginal effects (AME) of the point estimates over the predicted binomial distribution function.

To interpret the statistical significance of the results, we look at the 95% Bayesian credible intervals. According to Kruschke et al. (2012), we can conclude the statistical significance if the values that lie within the 95% Bayesian credible intervals have the same direction as the point estimate. As shown in Table 1 above, the variables *bribe*, *inspections*, *employees* on a log scale, and *credit* have a statistically significant positive association with the likelihood of engaging in R&D across all the estimations. The variables *political*,



K-fold IC	2727.136	2752.797	2809.867	2653.597
SE	681.232	681.703	710.539	666.934

Figure 2. K-fold model comparison. *Source: Authors' calculations based on 2016 and 2018 World Bank Enterprise Survey data for Lao PDR.*

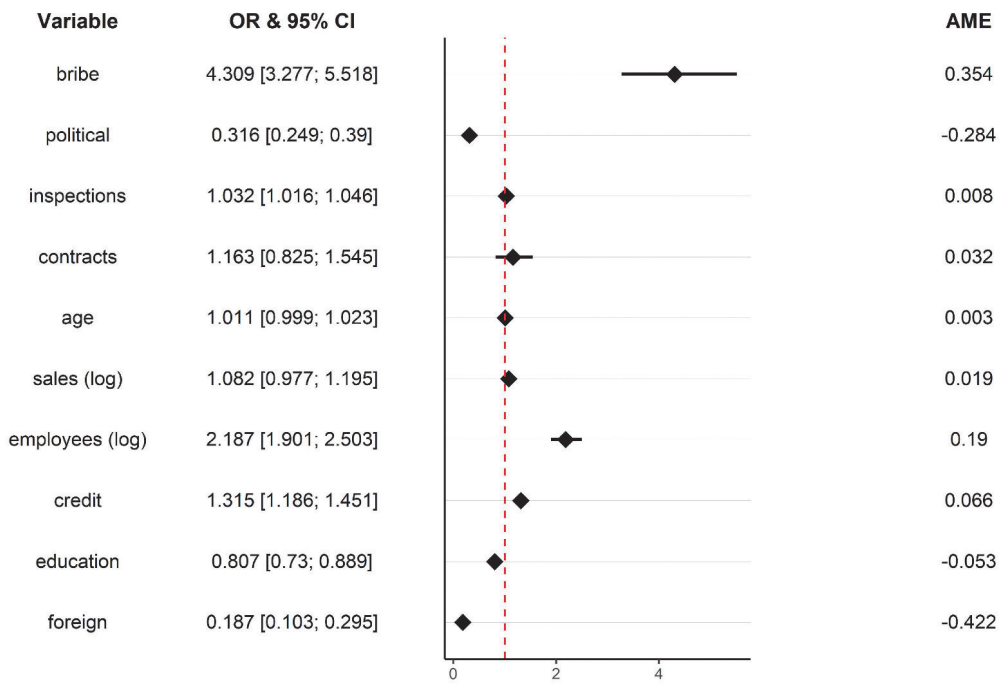


Figure 3. Odds ratios and average marginal effects of the baseline estimation estimated with weak empirical prior. Note: Year and sector dummies not reported.

Table 1. Comparison of estimation results across different priors.

Variables	Vague Student's t Prior	Vague Normal Prior	Weak Generic Prior	Weak Empirical Prior
Bribe	1.545	1.543	1.486	1.448
	[1.277; 1.807]	[1.271; 1.815]	[1.223; 1.741]	[1.187; 1.708]
Political	−1.17	−1.173	−1.167	−1.162
	[−1.398; −0.949]	[−1.413; −0.956]	[−1.408; −0.941]	[−1.389; −0.941]
Inspections	0.031	0.031	0.031	0.031
	[0.017; 0.045]	[0.017; 0.045]	[0.017; 0.044]	[0.016; 0.045]
Contracts	0.065	0.062	0.081	0.132
	[−0.268; 0.388]	[−0.271; 0.388]	[−0.253; 0.409]	[−0.192; 0.435]
Age	0.01	0.011	0.011	0.011
	[−0.002; 0.022]	[−0.002; 0.022]	[−0.001; 0.023]	[−0.001; 0.023]
Sales (log)	0.089	0.088	0.081	0.077
	[−0.013; 0.188]	[−0.02; 0.192]	[−0.022; 0.179]	[−0.024; 0.178]
Employees (log)	0.792	0.793	0.783	0.779
	[0.653; 0.93]	[0.648; 0.937]	[0.649; 0.927]	[0.642; 0.917]
Credit	0.271	0.272	0.274	0.272
	[0.167; 0.374]	[0.168; 0.383]	[0.168; 0.375]	[0.17; 0.372]
Education	−0.226	−0.227	−0.222	−0.216
	[−0.322; −0.131]	[−0.321; −0.133]	[−0.314; −0.127]	[−0.314; −0.117]
Foreign	−2.09	−2.087	−1.845	−1.727
	[−2.762; −1.486]	[−2.765; −1.492]	[−2.41; −1.32]	[−2.272; −1.221]
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes

Source: Authors' calculations based on 2016 and 2018 World Bank Enterprise Survey data for Lao PDR. .

education, and *foreign* have a statistically significant negative association with the likelihood of the firm engagement in R&D activities across all of the estimations. The variables *contracts*, *age*, and *sales* are statistically insignificant.

Discussion

Our results show that the likelihood of engaging in R&D among Lao SMEs has a positive and statistically significant association with the firm having experienced bribe solicitation by government authorities and with the firm having been subject to more frequent tax inspections. On average, firms that have experienced bribe solicitation are 35% more likely to engage in R&D activities than those who have not reported to have been subject to bribe solicitation. R&D is a capital-intensive activity, and investments in R&D are indispensable for innovation (B. Hall & Reenen, 2000; Frenkel et al., 2001; Shefer & Frenkel, 1998). Accordingly, R&D engagement is risky and has sunk costs. In R&D activities that require firms to obtain licences or permits or undertake other interactions with the government, public officials may have rent seeking incentives under a weak institutional environment and use their monopoly power for bribe solicitation. Firms, in turn, may choose to bribe if the transaction cost is rationally justified and the institutional environment does not sanction bribery by moral or legal measures. This can lead to bribery functioning as a facilitating factor for R&D engagement, supporting the hypothesis of a 'grease the wheels' effect (Lui, 1985) of corruption on firm innovation. This result is consistent with the empirical findings of Nguyen et al. (2016) and Lin et al. (2010), who found a positive association between bribery and innovation among Vietnamese and Chinese firms. Some other studies in Asian countries have found evidence on the grease the wheel effect that corruption could have on firm performance (see, e.g. Chen et al., 2013; Vial & Hanoteau, 2010). Corruption may thus be only the second-best option to overcome inefficiency in a weak institutional environment (Ashyrov, 2020).

Our results also indicate that firms that engage in R&D activities experience more frequent tax inspections. Firms that have more frequent tax inspections have 0.8% higher probability of being R&D investing firms. Although empirical evidence exists that tax exemptions and benefits may promote R&D (see, e.g. Czarnitzki et al., 2011), heterogeneous tax treatment requires more diverse control mechanisms for tax receipts, including increased tax inspections. Tax inspections, in turn, can be viewed as a time tax on firms and may deter managers from using their time resources for productive activities (De Rosa et al., 2015). Contrary to the anticipation of benefits of a lower tax burden for firms, the transaction costs from additional reporting and tax audits may reduce or even outweigh the benefits, thereby discouraging firms from R&D engagement. The negative effect of government inefficiency on R&D has also been reported by Lin et al. (2010) as resulting eventually in lower R&D engagement. This is consistent with the finding of Ayyagari et al. (2010) that innovative firms spend more time with government officials than non-innovative firms.

The results also show a negative association between the perception of political uncertainty and R&D engagement. Firms that perceive political uncertainty as an obstacle to doing business are 28% less likely to engage in R&D activities. In contrast, the results show a positive association between government contracting and R&D engagement among Laos SMEs, although the effects are insignificant because of the size of the confidence intervals. The findings concerning low apprehension of political uncertainty can be explained by the nature of the Communist political system in Laos with one-party rule.

Conclusions

This study investigated how firms' perceptions of the institutional environment are related to the firms' willingness to undertake highly uncertain R&D investment decisions, in the context of the transitioning economy of Laos in Southeast Asia. The main argument of this paper is that the institutional setting may be related to firms' R&D engagement decisions via three channels: (i) political uncertainty, (ii) bribe solicitation by the government, and (iii) frequent tax inspections by the government. To analyse these relationships empirically, we employed data from the World Bank Group Enterprise Surveys for the years 2016 and 2018 in Laos, following the frameworks of Johnson et al. (2002), Cull and Xu (2005), and Lin et al. (2010). We employed a Bayesian econometrics framework, along with multivariate imputations by chained equations, to address the potential risks of reporting bias associated with missing observations and incidental parameter estimates resulting from the availability of mainly binary and ordered data.

The empirical findings of this study demonstrate that Lao SMEs that invest in R&D experience greater government solicitation of bribes. Informal payments to government officials may have a facilitating role in the R&D engagement of firms in countries with cumbersome business regulations and weak institutional environments. Despite some efforts of the Lao government to impose easy corporate taxation principles for SMEs, we found that companies engaging in R&D investments are more frequently subject to tax inspections, resulting in a potential time tax effect on firms in Laos that invest in R&D.

There are, however, certain limitations to our findings concerning the role of the institutional setting in Laos on the R&D investment decisions of SMEs. First, data used do not reflect whether firms invest in basic development, applied research, or experimental development. Hence, the degree of innovation incentives among firms remains unclear. Second, because the information available about the firms' experience with bribery solicitation by government was limited, although numerous firms admitted experiencing corruption in their interactions with government officials, information on the degree of such exploitation by government was revealed by only a fraction of the firms represented in the dataset. Third, potential endogeneity in the frequency of tax inspections and bribe solicitations, accompanied by limited data availability, limited us to being able to draw only tentative conclusions about the associations between R&D engagement and the independent variables used in the analysis. Although Bayesian regression analysis with prior information partially alleviates the problem by supplying additional information to the model, it does not address this limitation completely. Additional research is needed on the occurrence and magnitude of government solicitation of bribes from the firms.

Despite the limitations mentioned above, the findings of this study concerning associations detected between the likelihood of SMEs in Laos engaging in R&D activities and those SMEs' perceptions of the institutional environment call for a policy conclusion in favour of strengthening property protection in Laos and addressing the potential pitfalls of the country's governance and law enforcement.

Notes

1. See, for example, Egbetokun et al. (2008) for a study of industry-wide innovation in India, Sivak et al. (2011) for a study of firm-level R&D and innovation in Eastern European countries,

de Waldemar (2012) for a study of R&D and innovation among Indian firms, and Sharma and Mitra (2015) for a study of innovation among Indian firms.

2. Lin et al. (2010) conducted a study of R&D investment decisions among Chinese firms. China is a rapidly developing economy that is no longer near the bottom of the world's wealth distribution. Sivak et al. (2011) included a binary R&D engagement variable in their analysis, but the focus of the study was primarily on innovation incentives rather than innovative input.
3. World Bank, available at https://www.worldbank.org/en/topic/smefinance.
4. SMEs that are not registered under the Value Added Tax (VAT) system are subject to lump-sum tax instead of profit tax. This applies to enterprises which have annual revenue of less than LAK 12 million.
5. Lao PDR: Economic Recovery Challenged by Debt and Rising Prices, available at https://www.worldbank.org/en/news/press-release/2022/05/12/lao-pdr-economic-recovery-challenged-by-debt-and-rising-prices.
6. Extensive review about Lao PDR political leadership is provided by Pratt and Yongvanit (2016).
7. Although there exist officially eight political parties in China compared to the one political party in Laos, all the eight political parties in China are subservient to Chinese Communist Party.
8. Endogenous growth literature (see for example G. M. Grossman & E. Helpman, 1991; Jones, 1995; P. M. Romer, 1986; P. Romer, 1990) emphasises the endogenous technological component achievable through research and development in achieving the long-run economic growth. In a steady state, this means that with the increased input in research and development, the output of that R&D should grow proportionally to input. However, this is not the case in most modern industrialised economies. The research and development output has grown proportionally slower than the inputs have increased (Jones, 1995). Jones and Williams (2000) argue that such underinvestment in research and development compared to the available inputs occurs because of the appropriability problems, knowledge spillovers, creative destruction, and congestion externalities related to the research and development.
9. We used the MICE package in R to perform multiple imputations. See Van Buuren and Groothuis-Oudshoorn (2011).
10. We used the BRMS package in R for Bayesian estimations. See Bürkner (2017).
11. For a vague prior, we applied a prior that conformed to a normal distribution with a mean of zero and a standard deviation of 10, formulated mathematically as $\beta_{x_i} \tilde{N}ormal(0, 10)$, and a Student's t distribution prior with a location of zero, a scale of 10, and 3 degrees of freedom, formulated as $\beta_{x_i} \tilde{S}tudent(3, 0, 10)$.
12. The generic weakly informative prior can be formulated as a prior with a mean of zero and a standard deviation of 1, formulated mathematically as $\beta_j \tilde{N}ormal(0, 1)$ (Gelman et al., 2008).
13. $\beta_{x_i} \tilde{S}tudent(3, 0, 2.5)$, which is equivalent to Gelman et al. (2008)'s $\beta_j \tilde{C}auchy(0, 2.5)$ prior.
14. We used a weakly informative normal distribution prior with a standard deviation of 1 and mean of 1 or−1, depending on the expected association.

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Appendices

Appendix A.1. Description of the variables

Table A1. List of Variables.

Variable	Description	Type
rd	The firm has engaged in formal R&D activities during the last fiscal year (*rd* = 1)	Binary
bribe	During tax inspections, firm experienced or was asked for gifts or informal payments (*bribe* = 1)	Binary
political	Political instability as an obstacle to doing business: 0 = no obstacle, 1 = minor obstacle, 2 = moderate obstacle, 3 = major obstacle, 4 = very severe obstacle	Ordinal
inspections	Frequency of tax inspections during the last fiscal year	Continuous
contracts	The firm has secured or attempted to secure contracts with government (*gov_contracts* = 1)	Binary
age	Firm age calculated from the firms' establishment date and limited to 50 years	Continuous
employees	Number of employees, full-time equivalent	Continuous
sales	Firm total sales revenues during the last fiscal year in local currency units	Continuous
credit	Credit constraints as an obstacle to doing business: 0 = no obstacle, 1 = minor obstacle, 2 = moderate obstacle, 3 = major obstacle, 4 = very severe obstacle	Ordinal
education	Apprehension of human capital availability as an obstacle to doing business: 0 = no obstacle, 1 = minor obstacle, 2 = moderate obstacle, 3 = major obstacle, 4 = severe obstacle	Ordinal
foreign	50% or more of firm is foreign owned (*foreign* = 1)	Binary

Source: Authors' calculations based on 2016 and 2018 World Bank Enterprise Survey data for Lao PDR.

Appendix A.2. Summary Statistics

Table A2. Summary Statistics.

Variable	Obs	Frequency	Mean	SD	Min	Max
rd	614		0.049	0.216	0	1
Yes (1)		30				
No (0)		584				
bribe	511		0.184	0.388	0	1
Yes (1)		94				
No (0)		417				
political	589		0.550	0.841	0	4
No obstacle (0)		362				
Minor obstacle (1)		161				
Moderate obstacle (2)		42				
Major obstacle (3)		17				
Severe obstacle (4)		7				
inspections	533		4.441	5.854	1	60
contracts	610		0.105	0.307	0	1
Yes (1)		64				
No (0)		546				
age	614		14.847	9.047	1	50
employees	614		42.744	135.845	1	2002
sales	614		864008	4684826	1171	95103936
credit	614		1.117	1.138	0	4
No obstacle (0)		238				
Minor obstacle (1)		172				
Moderate obstacle (2)		119				
Major obstacle (3)		64				
Very severe obstacle (4)		21				
education	614		1.223	1.266	0	4
No obstacle (0)		240				
Minor obstacle (1)		156				
Moderate obstacle (2)		98				
Major obstacle (3)		81				
Very severe obstacle (4)		39				
foreign	614		0.075	0.263	0	1
Yes (1)		46				
No (0)		568				

Source: Authors' calculations based on 2016 and 2018 World Bank Enterprise Survey data for Lao PDR.

Appendix A.3. Correlation Matrix

Table A3. Correlation Matrix.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) *rd*	1										
(2) *bribe*	0.029	1									
(3) *political*	−0.022	0.182	1								
(4) *inspections*	−0.009	−0.070	−0.054	1							
(5) *contracts*	0.076	0.087	−0.043	−0.012	1						
(6) *age*	0.030	−0.041	0.016	−0.047	0.012	1					
(7) *employees*	0.084	0.020	0.049	−0.046	0.056	0.131	1				
(8) *sales*	0.024	0.065	0.086	−0.019	0.080	0.113	0.462	1			
(9) *credit*	−0.055	0.053	0.235	−0.010	−0.031	−0.082	−0.054	−0.022	1		
(9) *education*	−0.059	−0.019	0.204	−0.152	−0.050	0.046	0.102	0.034	0.376	1	
(11) *foreign*	−0.067	0.015	0.042	−0.098	0.052	−0.029	0.286	0.244	−0.008	0.097	1

Source: Authors' calculations based on 2016 and 2018 World Bank Enterprise Survey data for Lao PDR.

Appendix 3

THE ROLES OF FOREIGN AND DOMESTIC OWNERSHIP IN THE CORRUPTION–FIRM INNOVATION NEXUS

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RESEARCH ARTICLE

The roles of foreign and domestic ownership in the corruption–firm innovation nexus

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Abstract

Previous literature has shown the detrimental impact of corruption on innovation. Conversely, the grease-the-wheel effect, in bribing fuelling firm innovation, has found some empirical support too. Past studies show that foreign-owned firms largely outperform domestic firms in innovation activities. However, little is known about how corruption in developing countries might shape the advantages of foreign-owned firms to innovate. We explored whether bribery, as an institutional dysfunctionality, is differently associated with innovation in the context of foreign owned versus domestically owned firms that operate in overall low research and development intensive economies and engage in exporting. By applying recursive bivariate probit regression, we investigated the link between bribery and innovation engagement among 4118 domestically and foreign-owned exporting firms from 34 developing countries, using data from the World Bank Enterprise Surveys and other databases. We find evidence on the grease-the-wheel effect so that bribery has a stimulating effect on innovation among domestically as well as foreign-owned exporting firms. These findings underscore the importance for developing countries of finding institutional and policy solutions to coordination failure in combatting corruption.

KEYWORDS
corruption, firm innovation, institutions, ownership type

JEL CLASSIFICATION
D73, O17, O19, O30

1 | INTRODUCTION

Innovation is a key driver in achieving productivity and economic growth (Aghion & Howitt, 1992; Grossman & Helpman, 1991; Romer, 1990). Among the many well-established antecedents of innovation, a country's institutional setting and foreign direct investments (FDIs) are of prominent importance (Lin et al., 2010; Qu et al., 2017). A reliable institutional setting can encourage productivity enhancement (Dollar & Kraay, 2003), whereas an improperly functioning institutional environment may often result in unproductive behaviors (Greif, 2006). A proper institutional setting may decrease transaction costs and uncertainty between economic agents (Alonso & Garcimartín, 2013). The institutional setting may also be related to a firm's tendency to innovate in various ways, such as by corruption and property rights protection (Barasa et al., 2017).

Previous studies have emphasized the dominance of foreign-owned firms over domestic owned firms in productive activities (Guadalupe et al., 2012), especially in developing countries (Ramondo, 2009). Developing countries are often unable to use their resources fully because of inadequate human and physical capital and technological competence (Iamsiraroj & Ulubaşoğlu, 2015) and may prefer to compensate for these inadequacies by relying on foreign technology and investors. Evidence suggests that inward FDI flows are important for economic growth in developing countries (Aitken & Harrison, 1999; Blomström & Sjöholm, 1999). FDI as a package of technological, managerial knowledge, and financial capital plays an essential role in transferring advanced foreign technology to developing countries (Dunning, 1994; Fu et al., 2011). Several lines of empirical evidence suggest that technology can be transferred to firms mainly via direct foreign linkages (Damijan et al., 2003). Foreign research and development (R&D) and FDIs lead to significant productivity improvements and value-added growth (Savvides & Zachariadis, 2005) by restructuring production and developing global linkages (Arnold & Javorcik, 2009).

In light of the importance of foreign investments and the local institutional setting to productive activities, we sought to examine the roles of foreign and domestic ownership in corruption and the firm innovation nexus. Such a distinction is not only novel in the area of corruption studies but also important. Differences in the innovativeness of foreign-owned and domestically owned companies competing in the same country are not ambiguous (Un, 2011). Studies on developing and transition economies suggest that foreign-owned firms tend to be more productive than domestically owned firms, and this divergence does not seem to diminish over time (Arnold & Javorcik, 2009; Estrin et al., 2009), because domestically owned firms are more financially constrained than foreign-owned firms (Girma et al., 2008). Access to external financing is associated with greater firm innovation (Ayyagari et al., 2011). These constraints limit the capabilities of domestically owned firms to innovate and close the gap between foreign-owned firms and themselves (Gorodnichenko & Schnitzer, 2013).

This investigation also addressed a much-debated question in the literature regarding the effect of corruption on firm innovation. One strand of studies focuses on the positive effect of corruption by supporting the grease-the-wheel hypothesis. According to this hypothesis, corruption can

be used as a tool to compensate for the sluggishness of inefficient bureaucratic systems in developing countries (Méon & Weill, 2010) as bribe may function as a supplement to bureaucrats' low wages which might become as an incentive for bureaucrats to accelerate the procedures (Leys, 1965). Hence, corruption could reduce significant queues and delays in bureaucratic procedures. In other words, firms might reduce transaction costs in an inefficient bureaucratic setting and could accelerate their productive activities. This hypothesis was tested by several empirical studies (e.g., Nguyen et al., 2016; Xie et al., 2019). For example, Krammer (2019) found that corruption can facilitate innovative firms' introducing new products by overcoming bureaucratic rigidities, compensating for the lack of kinship or political affiliations, and hedging against political risk. Furthermore, Xie et al. (2019) have indicated the role of weak institutional settings of developing countries in this positive association. In a weak institutional environment, bribing the public officials is not punished, as law enforcement is not effective; hence, bribing emerges a normal way of doing business for firms to accelerate their operations (Ashyrov, 2019).

One group of studies (e.g., de Waldemar, 2012; Paunov, 2016) finds evidence for a sand-the-wheel effect of corruption, which is a negative relationship between corruption and firm innovation. The main explanation for these findings is that corruption creates costs and uncertainty for firms that may be difficult for innovative firms to cope with in the long term, so these costs and uncertainties function as important deterrents to innovation. Previous literature has emphasized the importance of the business environment, especially competitiveness and dynamism, for the effectiveness of innovation strategies (Prajogo, 2016). In this way, governments aim to invest in infrastructure for creating available business environments for exporting SMEs, this may not be realized as desired due to detrimental effect of corruption on business environment such as infrastructure related project (Gillanders, 2014) which is also important factor for the growth (Esfahani & Ramıŕez, 2003) and firm to perform productivity activities (Fernald, 1999). Therefore, curbing corruption in infrastructure, by triggering dynamism and facilitating necessary factors, would be anticipated to boost innovation activities. Furthermore, corruption also negatively impacts the business environment by damaging competition, increasing extortion risk (Huang & Yuan, 2021), hampering international trade (De Jong & Bogmans, 2011). Therefore, corruption through its deteriorating effect on business environment could discourage exporting SMEs from investing in innovation activities.

In this study, we made use of firm-level data on 34 developing countries from the World Bank Enterprise Surveys (WBES) database, and other country-level control variables from the World Bank (WB), World Bank Governance Indicators (WGI), and Global Innovation Index (GII) databases. We applied the recursive bivariate probit regression maximum likelihood estimation method to estimate the effect of bribery, as a form of corruption, and the firms' innovative engagement among domestically and foreign-owned exporting firms. This study excludes non-exporters from the empirical analysis for alleviating the innovation measurement problem. The paper focuses on extensive and competitive market innovation pursued by the exporters and separates it from the local innovation that is mostly carried out by non-exporters who invent and improve business practices within a specific local context only (Hoffecker, 2018) This reasoning is in line with earlier studies explaining differences between exporters and non-exporter via self-selection effects (e.g., Bernard & Jensen, 1999). According to this view exporting firms tend to be more productive (Clerides et al., 1998) and their innovation is more substantial compared to non-exporting firms (Criscuolo et al., 2010; Şeker, 2012; Azar & Ciabuschi, 2017).

Previous studies in this area have put little emphasis on the type of innovation and have often focused on specific innovation proxies in relation to corruption. Such a focus may fail to provide a clear picture of the effect of corruption on a specific innovation type. Thus, we assumed

that firms may undertake different types of innovation, such as product and process innovation, as these may add different values to the firm profits (Teece, 1986). In addition, corruption could affect product and process innovation activities. For example, public officials may ask for bribes from product innovators in exchange for granting a patent for a newly developed product (Goel & Saunoris, 2020). In the context of process innovation, corruption could affect the probability of process innovation taking place (Goel & Nelson, 2018) by increasing the costs of firms' investments in machinery, which are important to introducing innovations (Paunov, 2016).

This study found a positive link between bribery and firm innovation in our country sample, which supports the hypothesis of a grease-the-wheel effect of corruption on firm innovation among exporters in developing countries with overall low R&D intensity. To examine the role of ownership in the link between corruption and firm innovation, we divided the data sample into two groups, foreign-owned and domestically owned exporting firms, and we obtained intriguing findings. Our results reveal that corruption is similarly associated with the innovation activities of both foreign-owned and domestically owned exporting firms in the sample. One possible explanation for this result is that the behaviors of foreign-owned and domestically owned exporting firms may exhibit no differences with respect to corruption, as foreign firms may adopt local practices and ways of doing business in developing countries with often weak institutions, in order to maintain innovative activities (Webster & Piesse, 2018). In addition, the positive association between the innovation activities of foreign-owned exporting firms and bribery in the study sample could be related to the foreign owner's ability to access financing. In this way, foreign-owned firms may overcome the cost of corruption abroad, whereas domestically owned firms may take advantage of corruption to accelerate their innovative activities using their established political and corrupt connections in a developing economy with institutional weaknesses and overall low innovation engagement (Ashyrov & Masso, 2020).

The remainder of the paper is organized as follows. The second section summarizes the data used in the empirical analysis. The third section presents the methodology used, and the fourth section presents the results obtained. A discussion of these results and the conclusions drawn from them are presented in the last section.

2 | DATA

We used firm-level data retrieved from the WBES database for a sample of 4118 firms from 34 developing countries around the world (see Table A1) for which the data for firms innovative and bribing activities were present for both foreign and domestically owned firms. The classification of country development level relied on United Nations Statistics Division classification. The firm-level data included observations from all available industries from both the manufacturing and service sector surveys under WBES (see Table A2). Country-level control variables were retrieved from the WB, WGI, and GII databases to control for country-level effects.

We measured firm innovation engagement using three different dichotomous measures of the firm's self-reported innovation outputs. The first variable, "innoprod," represents the firm's choice to engage in product innovation and takes a value of one if the firm has introduced new or significantly improved products and zero otherwise. The second variable, "innoprocess," represents the firm's choice to engage in process innovation and takes the value of one if firm has introduced new or improved process. The third variable, "inno," combines the outcomes of two latter variables and takes a value of one if the firm has introduced either product or process innovation. Similar innovation definitions have been used in numerous earlier studies (see Ayyagari et al., 2011;

TABLE 1 Marginal effects of the simple probit regression on likelihood of a firm engaging in innovation.

	Product innovation beta/se	Process innovation beta/se	Overall innovation beta/se
Bribe	−0.0156	0.1880**	0.2316**
	(0.0488)	(0.0898)	(0.0904)
Group	0.0115	0.0426	0.0477
	(0.0285)	(0.0317)	(0.0321)
Age (log)	−0.0464***	−0.0062	−0.0179
	(0.0176)	(0.0211)	(0.0205)
Diversity	−0.0024***	−0.0014*	−0.0020**
	(0.0008)	(0.0009)	(0.0009)
Employees (log)	0.0164	0.0182*	0.0242**
	(0.0101)	(0.0102)	(0.0104)
Skilled	−0.0035	−0.0037	−0.0065
	(0.0040)	(0.0038)	(0.0042)
Qualitycert	0.0066	−0.0126	−0.0184
	(0.0282)	(0.0313)	(0.0321)
R&D	0.2952***	0.4269***	0.4615***
	(0.0292)	(0.0296)	(0.0350)
Innoindex & ruleoflaw (pc1)	−0.0668***	0.0022	−0.0045
	(0.0129)	(0.0146)	(0.0140)
Observations	4128	4128	4128

Notes: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported.
Source: Compiled by the authors.

Barasa et al., 2017; Capitanio et al., 2010; Cirera & Sabetti, 2019; Damijan et al., 2010; Goedhuys & Veugelers, 2012; Michailova et al., 2013; Van Beveren & Vandenbussche, 2010 among others).

Identifying innovation activities based on the above variables in the given sample brings along some limitations. First, the sample is dominated by small and medium-sized firms operating in countries with overall low R&D intensity, resulting in self-reported innovations being potentially rather incremental than substantial, in which cases Santarelli and Sterlacchini (1990) have argued in favor of using more direct innovation measurement. More detailed innovation data, however, were not available for our sample.

Second, a considerable amount of self-reported innovation in developing countries may represent an imitation of past innovations by more developed countries and companies rather than original innovation (Smith, 1999). Regardless of these limitations, the product and process innovation measures we used still reflect some (desired) advancements of the firm in the value chain or improvements in the competitive advantages of the firms (Männasoo et al., 2018).

Another key variable in our analysis is the variable "bribe," which is a self-reported dichotomous variable and takes a value of one if government officials have asked the firm for informal gifts or informal payments. According to Lin et al. (2010), the act of requesting informal payments or gifts by government officials reflects the one dimension of government grabbing hand that increases the cost of doing business and decreases innovation returns, and thus, reduces

TABLE 2 Marginal effects of the likelihood of a firm engaging in innovation and bribery.

	Product innovation		Process innovation		Overall innovation	
	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1
	beta/se	beta/se	beta/se	beta/se	beta/se	beta/se
Bribe	0.2311**		0.4986***		0.5793***	
	(0.0911)		(0.1472)		(0.0641)	
Group	0.0132	−0.0312	0.0541*	−0.0233	0.0595**	−0.0381
	(0.0289)	(0.0298)	(0.0300)	(0.0455)	(0.0302)	(0.0429)
Age (log)	−0.0458**	−0.0565***	0.0032	−0.0151	−0.0053	−0.0361
	(0.0179)	(0.0183)	(0.0227)	(0.0248)	(0.0213)	(0.0255)
Sales (log)		−0.0016		−0.0057		−0.0060
		(0.0034)		(0.0089)		(0.0088)
Diversity	−0.0023***	−0.0024***	−0.0012	−0.0019**	−0.0018**	−0.0031***
	(0.0008)	(0.0008)	(0.0009)	(0.0009)	(0.0008)	(0.0010)
Employees (log)	0.0137	0.0099	0.0152	0.0170	0.0205**	0.0238
	(0.0102)	(0.0107)	(0.0101)	(0.0132)	(0.0097)	(0.0148)
Skilled	−0.0035	−0.0053	−0.0030	−0.0101*	−0.0054	−0.0149**
	(0.0038)	(0.0039)	(0.0036)	(0.0056)	(0.0039)	(0.0061)
Qualitycert	0.0087	0.0016	−0.0060	−0.0208	−0.0095	−0.0216
	(0.0281)	(0.0287)	(0.0283)	(0.0422)	(0.0284)	(0.0467)
R&D	0.2857***	0.2779***	0.3904***	0.4747***	0.4100***	0.5368***
	(0.0296)	(0.0361)	(0.0356)	(0.0456)	(0.0342)	(0.0545)
Import license		0.0699***		0.1584*		0.2027***
		(0.0266)		(0.0940)		(0.0649)
Electric connect		−0.0339		−0.0814		−0.1111*
		(0.0223)		(0.0629)		(0.0598)
Bureaucracy		0.0214**		0.0511		0.0648***
		(0.0094)		(0.0334)		(0.0203)
GDP (log)		−0.0310*		−0.0682**		−0.0835***
		(0.0182)		(0.0328)		(0.0274)
Population (log)		0.0046		−0.0031		0.0010
		(0.0070)		(0.0132)		(0.0135)
Export		0.0023**		0.0044**		0.0057***
		(0.0010)		(0.0019)		(0.0013)
pc1 (innoindex & ruleoflaw)	−0.0523***	−0.0675***	0.0056	−0.0314	0.0007	−0.0469**
	(0.0122)	(0.0137)	(0.0102)	(0.0231)	(0.0099)	(0.0221)
Observations	4128		4128		4128	

(Continues)

TABLE 2 (Continued)

	Product innovation		Process innovation		Overall innovation	
	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1	Marginal probability to innovate	Conditional probability to innovate at bribe = = 1
	beta/se	beta/se	beta/se	beta/se	beta/se	beta/se
Log likelihood	−65,081.407		−65,648.781		−64,757.634	
Wald chi^2 (30)	499.255***		485.562***		636.673***	
Rho	−0.480		−0.736		−0.869	
athrho	−0.523***		−0.941*		−1.328***	
LR test of rho = 0	8.863***		2.960*		14.740***	

Notes: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported.
Source: Compiled by the authors.

TABLE 3 Marginal effects of the likelihood of a firm engaging in innovation and paying bribe to government officials.

	Foreign firms	Domestic firms
Product innovation	0.1868**	0.2926***
	(0.0929)	(0.0682)
Process innovation	0.1507	0.2478***
	(0.1042)	(0.0773)
Overall innovation	0.2139***	0.3149***
	(0.0812)	(0.0675)

Notes: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported.
Source: Compiled by the authors.

firms' likelihood for innovation engagement. In addition, the "bribe" variable has potentially endogenous properties with respect to firms' innovative activities. As argued by Xie et al. (2019), innovating may require firms to obtain different permits and licenses, increasing interactions with government officials. This creates a higher reliance on the government and increases the risk of experiencing bribe requests.

Following Ashyrov and Masso (2020), we classified firms into foreign-owned or domestically owned subsets using a 10% foreign and domestic ownership threshold. All firms with any government or state ownership have been removed from the sample as this kind of firms may not operate on fully competitive grounds. Shaheer et al. (2019) concluded that the effects of bribing among state-owned firms differ significantly from private owned firms. Government owned firms tend to achieve their objectives through the political connections, but in the deteriorated institutional environment and managerial rent-seeking, the likelihood of paying bribe disproportionally increases among state-owned firms compared to the privately owned firms.

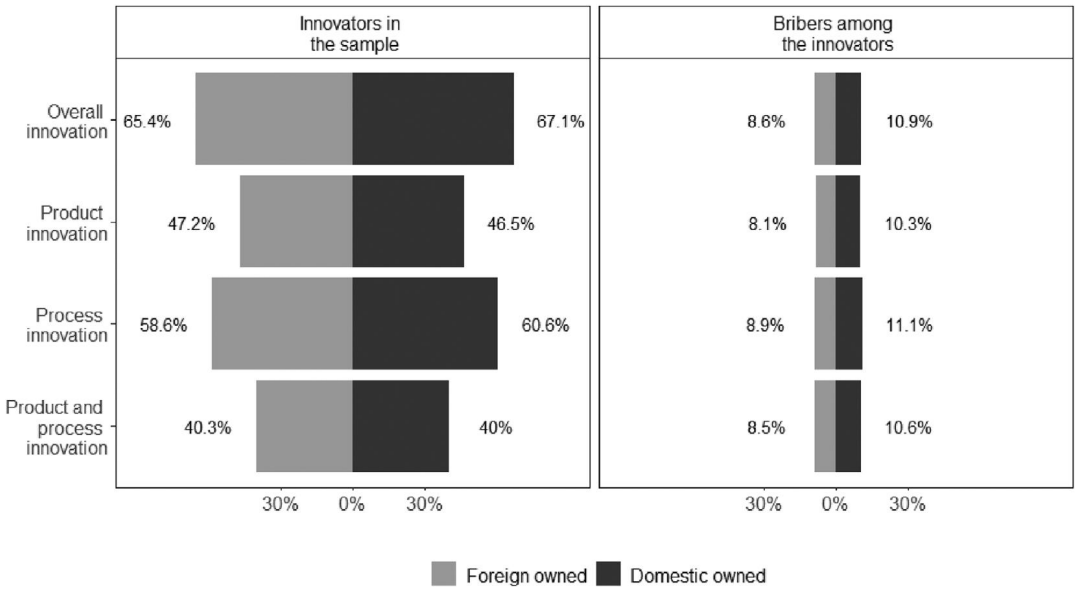

FIGURE 1 Distributions of innovation and bribing in the sample by firm ownership. *Source:* Compiled by the authors based on WBES data.

The sample is also restricted to exporting firms for two reasons. First, prior literature has presented that exporting firms tend to learn from doing business internationally (Bratti & Felice, 2012; Fabling & Sanderon, 2013; Rodil et al., 2016) and have higher productivity levels than non-exporting firms (Basile, 2001). Therefore, considering exporting firms only for the empirical analysis leads to a more homogenous sample in the presence of the above-discussed limitations that are caused by self-reported innovation outcomes among firms that operate in low R&D intensive economies. Second, innovativeness represents a competitive advantage, which explains the considerable variation in firms' export behavior (Basile, 2001). This results in endogeneity between innovating and selection to exporting meaning that more productive and innovative firms self-select to engage in exporting activities.

Figure 1 illustrates the distributions of firms engaged in innovation and those among them engaged in bribing in the sample, by foreign versus domestic ownership.

In line with previous literature on innovation (Aghazada & Ashyrov, 2022; Leiponen, 2012) we control for several firm-level variables. The "group" is a binary variable that reflects if a firm is a part of a larger establishment by taking a value of one if so. Variable "age" represents the firm's age calculated from the date the firm began its operations. "Employees" indicate the number of employees, capturing the size of the firms. The "sales" variable represents the firm's sales revenues for the last fiscal year. Since the WBES reports the firm's sales revenues in local currency units, we convert the revenues to United States Dollars using historical exchange rates provided by the United Nations Conference on Trade and Development.

Firms' product portfolio diversification (diversity), possession of quality certification (qualitycert), and skilled labor proportion (skilled), and engagement in R&D activities, are used as controls to account for firms' innovative capabilities. "Diversity" captures the percentage of sales revenues generated by the firm's primary business line, that is, the lower the diversity is, the more diversified the firm's sales portfolio is. "Qualitycert" is a binary variable that takes a value of one for

firms that have obtained internationally recognized certifications. "Skilled" indicates the percentage of skilled labor with a university degree, reflecting the stock of human capital. "R&D" is a dichotomous variable that takes a value of one if the firm has reported R&D activities and zero if not.

Furthermore, we included variables that might be a proxy for situations where the possibility of government officials demanding bribes or informal payments from firms is higher through their increased interactions. "Bureaucracy" is an ordinal variable which captures tax administration as a self-perceived obstacle on a scale from 0 (no obstacle) to 4 (major obstacle). "Electric connect" and "import license" are binary variables that indicate whether the firms have interacted with government officials to obtain electricity-related infrastructure connections (De Rosa, 2010) or import licenses.

To account for the country-level effects related to institutional quality, innovativeness, foreign trade, and economic development, we have included variables such as rule of law (ruleoflaw), innovation index (innoindex), export as a percent of GDP (export), purchasing power parity adjusted GDP per capita (GDP), the size of population (population), and vectorized country dummies.

A detailed overview of the countries and regions in the sample, the number of observations per country and industry, variable descriptions, summary statistics, and the correlation matrix obtained are given in Tables A1–A4 and Figure A1.

3 | METHODOLOGY

The WBES database provides representative data about a country's private sector firms. The survey covers a broad range of indicators of business conditions in different economies. The survey respondents are primarily firm owners or employees in managerial positions, but they are allowed to ask for input from other employees specialized in the fields of specific questions. The WBES methodology employs stratified random sampling to divide different population units into homogenous groups. From these homogenous groups, simple random samples with equal probabilities for each subgroup member to be chosen for the survey are formed.[1]

Since some survey questions address government and bribe-related topics, the WB hires private contractors to conduct the surveys and provides full confidentiality to survey participants. Regardless of the confidentiality of survey responders, there are gaps in the answers that may lead to reporting bias. In addition, self-reporting bias may affect the results.

The problem of missing responses is not uncommon but often ignored, assuming that responses are missing at random or observed at random. However, in some cases, data are not missing at random, and ignoring the missing values may lead to biased estimates (Rubin, 1976, 1978). While for education-related studies, the assumption of observations missing at random can be generally made (Cox et al., 2014), such an assumption is often implausible for analysis of bribery, given the illegal nature of bribery (Lee et al., 2010).

To alleviate the influence of reporting bias in the data and increase efficiency, we used multiple imputations to impute the missing values in those variables justified by Cox et al. (2014) in an education study and Lee et al. (2010) and Williams et al. (2016) in bribery-related studies. According to Graham (2009) and Cox et al. (2014), the advantage of multiple imputations over other missing data alleviation methods is the flexibility of the imputation process and the preservation of

[1] World Bank Enterprise Surveys methodology, available at: https://www.enterprisesurveys.org/en/methodology.

the underlying characteristics of the data in plugging in potential values of missing data points. The bribe variable was imputed using logistic regression with 600 preliminary imputations and 300 additional imputations, and the skilled variable was imputed using linear regression with 600 preliminary imputations. The potential measurement error arising from the self-reported nature of the data remains, unfortunately, a limitation of this study.

To account for the potential endogeneity between innovation and bribery, we applied a recursive bivariate probit model, which is a general-class simultaneous equation estimator first described by Heckman (1978) and Maddala (1983). Recursive bivariate probit enables joint estimation of two dichotomous choice probit models, where the binary dependent variable in one equation is the endogenous regressor in the second equation (Filippini et al., 2018). The endogeneity is addressed in a system of simultaneous equations, enabling correlation of error terms which in separate estimations would lead to inconsistent estimates. The system of recursive simultaneous equations builds on the following reduced-form equation of an endogenous dummy variable and structural equation of an outcome variable (Li et al., 2019; Monfardini & Radice, 2008; Wooldridge, 2010):

$$\begin{aligned} &D^* = X\beta_D + Z\gamma + \epsilon_2,\ D = \mathbb{I}(D^* > 0) \\ &Y^* = X\beta_Y + D\alpha + \epsilon_1,\ Y = \mathbb{I}(\mathrm{Y}^* > 0) \\ &\text{sothat}, \rho = cor(\epsilon_1, \epsilon_2), \neq 0, \end{aligned} \tag{1}$$

where Y^* and D^* are two latent variables representing the probability of innovating and the probability of bribing, respectively. X denotes a set of common covariates that explain innovation and bribing, and Z denotes the bribe-relevant instruments excluded from the innovation equation. $\mathbb{I}(\cdot)$ denotes the indicator function.

The models were estimated separately for each of the three innovation variables and the foreign and domestic ownership types. Following the set-up of recursive simultaneous systems defined in Equation (1), the endogenous bribe equation included all the covariates used in model parametrization. The innovation equation, on the other hand, included only those variables that were associated or correlated with the innovation outcomes and not with the endogenous bribe. Thus, we excluded from the innovation equation the variables sales, bureaucracy, import license, and electric connect that capture the firms' bargaining power and the necessity to interact with government officials rather than the subsequent innovation outcomes. As the variables innoindex and ruleoflaw are highly correlated, the first-order principal component was derived. That first-order principal component, reflecting the overall institutional quality for innovating in the country, was used in the innovation equation while the remaining country-level controls were used in the bribe equation only. Survey weights provided by the WBES were applied to the bivariate probit models to correct for the stratified random sampling design used by the WB. We use robust standard errors to correct for downward-biased standard errors.

4 | RESULTS

We begin our analysis by estimating univariate probit regressions for the total sample across all defined innovation outcomes, assuming no potential endogeneity between likelihood of innovating and bribery as pointed out by Xie et al. (2019). Table 1 summarizes average marginal effects of the probit regression estimates.

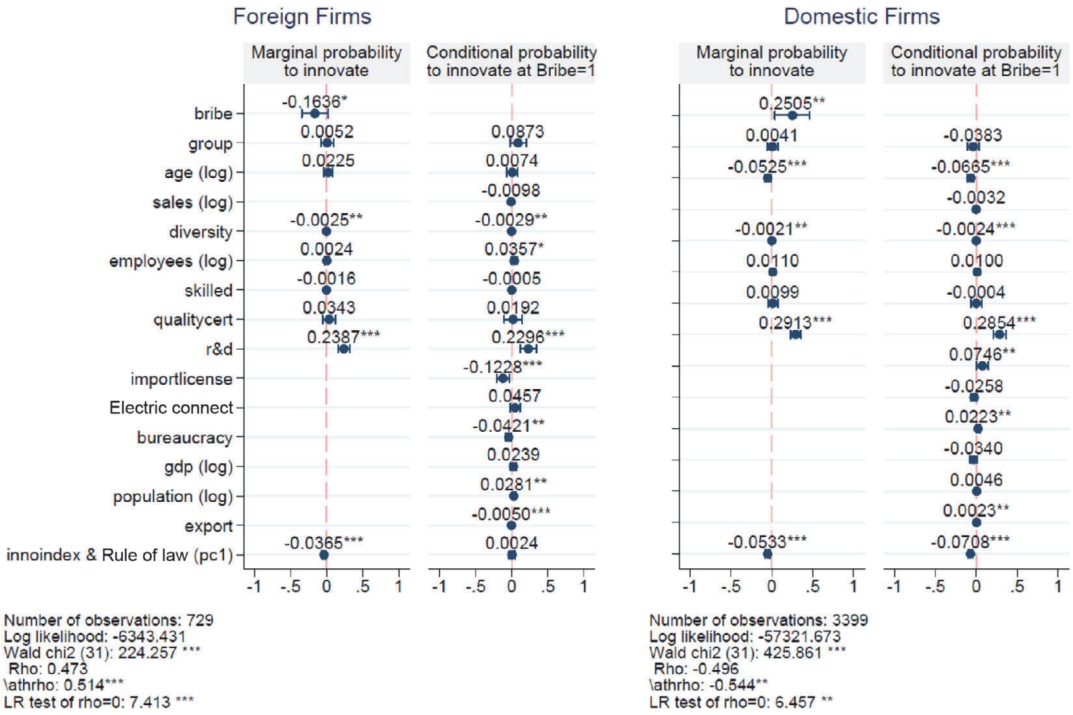

FIGURE 2 Marginal effects of the likelihood of a firm engaging in product innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors.
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Probit regression coefficients indicate that bribe has negative, yet statistically insignificant association with product innovation, but statistically significant positive association with process innovation and overall likelihood of innovating. Likelihood of introducing new or significantly improved products or processes is larger among firms who engage in R&D activities, which is considered indispensable input for innovating (see e.g., Huang & Rice, 2012). Portfolio diversity is also one statistically significant indicator across product and process innovators. Although product innovators tend to be relatively younger exporting firms, process innovators are usually larger in number of employees compared to non-innovators.

Next, we test if the assumption of endogeneity between innovation and bribe holds. For that reason, we estimate the recursive bivariate probit model that performs the likelihood ratio test for $\rho = 0$, which can be used as a Hausman endogeneity test (see Knapp & Seaks, 1998). The estimation results for the recursive bivariate probit models are presented in Table 2 and Figures 2–4. Table 2 outlines the estimation results for product innovation, process innovation, and overall innovation, with the firms with foreign and domestic ownership pooled. The estimation results are presented as marginal effects, with the marginal probability of a firm engaging in innovation $\mathbf{Pr}(\mathbf{Y} = 1)$ and the conditional probability of engaging in innovation $\mathbf{Pr}(\mathbf{Y} = 1, \mathbf{D} = 1)$ given a positive dichotomous choice to bribe ($\mathbf{Bribe} = 1$) shown separately. "Rho" represents the correlation of error terms, and "arthrho" is the inverse hyperbolic tangent transformation of the correlation term "rho." The marginal effects of the binary bribe variable are statistically signif-

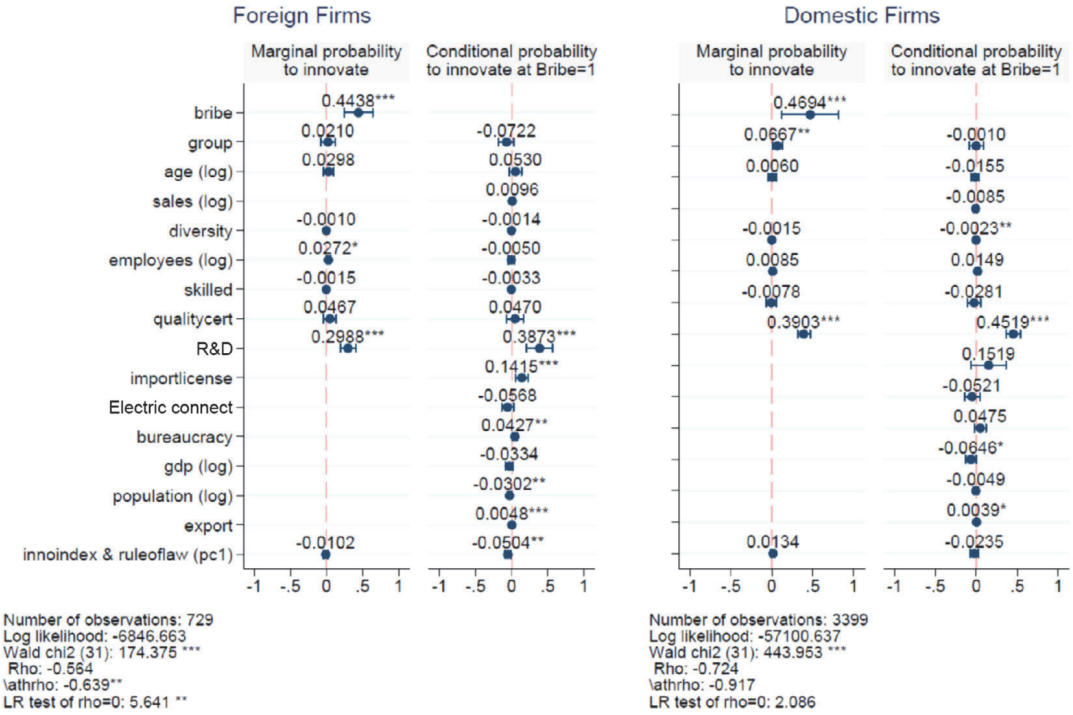

FIGURE 3 Marginal effects of the likelihood of a firm engaging in process innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors.
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icant and positive for all three measures of innovation, meaning that in our sample firms, bribing coincides with innovative activities. The transformed correlation of error terms is statistically significant for all three estimated models and indicates that simultaneous estimations are appropriate. The likelihood ratio test of rho = 0 indicates the acceptance of the alternate hypothesis and confirms the endogeneity assumption between the innovation engagement and bribe experience for all innovation types. Among the control variables, product diversity has negative and statistically significant coefficients, indicating that focusing on a main product would obstruct a firm from undertaking innovation activities, an expected result.

Next, we present the results for the subsamples of foreign and domestic ownership. The marginal effects of how bribery is associated with the firms' innovation engagement are shown in Figure 2 for product innovation and in Figure 3 for process innovation. In all of the estimations, the residuals' correlation term rho has a statistically significant Fisher *Z* transformation estimate, indicating that it is justifiable to estimate the models simultaneously.

Examining the estimation results for the firms' product innovation engagement in Figure 2, one can see that the marginal effects of bribery are positive and significant for both the foreign-owned and domestically owned firms. The simultaneous equations' residual correlation term, *rho*, has the same sign and is statistically significant for both ownership types. This indicates that, in addition to bribery involvement having a statistically significant effect on firms' innovation engagement in both subsamples, there is a similar dynamic in the predictability of bribery

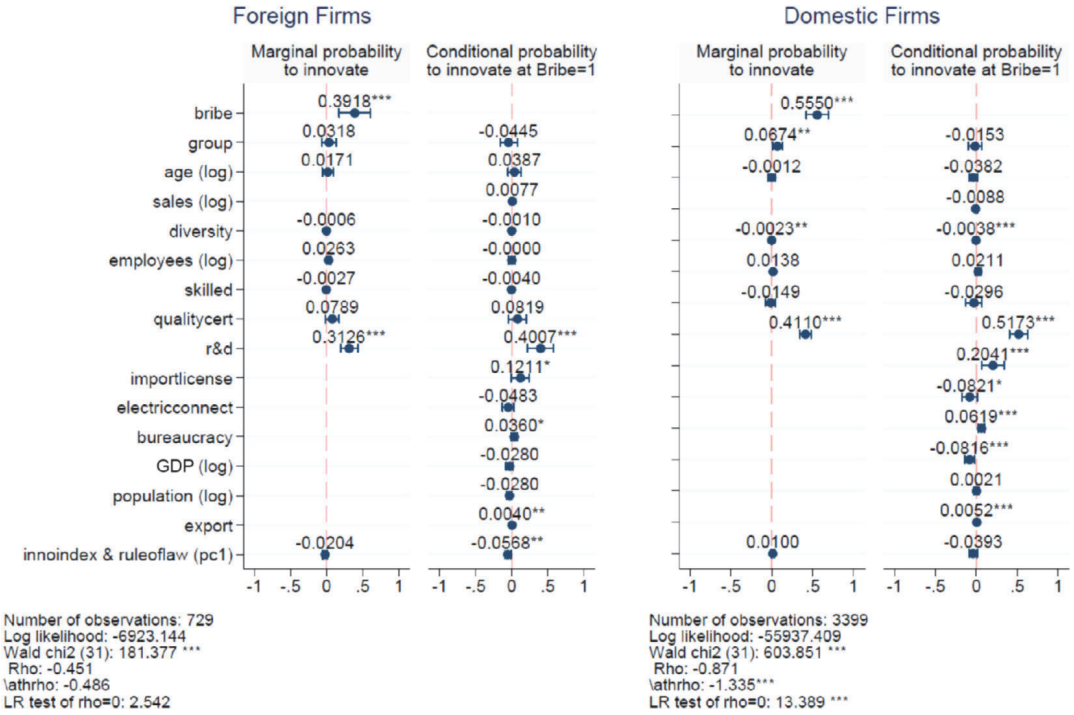

FIGURE 4 Marginal effects of the likelihood of a firm engaging in overall innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors.
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involvement and firms' product innovation engagement among foreign-owned and domestically owned firms. This means that for both the foreign and domestic firm ownership subsamples, increasing predictive power of the bribe-relevant regressors in the simultaneous endogenous treatment regression is associated with the increased predictive power of the innovation-relevant regressors' predictability of the outcome equation, in addition to the higher probability of engagement in innovation while being involved in bribing.

The process innovation marginal effects' estimates in Figure 3 exhibit patterns similar to those for product innovation. The marginal effects for the bribe variable are statistically significant for both foreign and domestic firm ownership. The involvement in bribery has a statistically positive association with both foreign-owned and domestically owned firms' process innovation engagement, and there is a strong positive correlation between the residuals of the simultaneous equations.

To perform an initial robustness check, we are using overall innovation engagement as an alternative dependent variable. Figure 4 provides estimation results for baseline estimations of the overall innovation engagement probability given the firms' ownership. These results show again that bribery is positively and statistically significantly related to overall innovation engagement for both foreign-owned and domestically owned firms.

We run further robustness checks to control whether the results are sensitive to the definition of bribery. To perform this task, we replace the initial bribe variable, which captures the association

between a firm experiencing government taking hand and the likelihood of engaging in innovation, with a dichotomous variable that takes the value of one if a firm has admitted to paying informal payments or gifts to government officials as a share of sales revenues. The summarized results are given in the Table 3 below. More detailed estimation results are available in Figures A2–A4.

Although the statistical significance between bribery and innovation engagement varies for foreign-owned firms, coefficients still reveal a positive relationship between bribery and innovation engagement among exporting firms that operate in developing countries regardless of the ownership status. Further, we explore if the results are robust to multiple chained imputations for bribery. The results for this are given in Figures A5–A7. Baseline conclusions remain unchanged for the imputation process. Next, we test if the results are sensitive to firms' exporting status by estimating the models for non-exporting firms only. The results for non-exporters are given in Figures A8–A10 for the baseline bribe specification and in Figures A11–A13 for the alternative bribe specification. The results for the bribe and the innovation outcome nexus remain unchanged for the non-exporting domestic firms. Under the baseline bribe specification, the results for the non-exporting foreign-owned firms, the relationship between bribery and innovation engagement is positive but not statistically significant.

5 | DISCUSSION AND CONCLUSIONS

In light of the adverse effect of corruption on economic development and yet the prevalence of bribery in developing economies, the goals of this study were twofold: to examine the effect of bribery on exporting firms' innovation engagement in developing countries and to better understand whether bribery affects foreign-owned and domestically owned firms' innovation in similar ways.

Previous studies have arrived at contradictory conclusions regarding the consequence of corruption on firm innovation. One stream of studies has claimed a positive effect of corruption, that is, the grease-the-wheel hypothesis (e.g., Xie et al., 2019), whereas another stream of studies has argued that corruption has a negative effect, that is, the sand-the-wheels hypothesis (e.g., Paunov, 2016). Our findings suggest that bribery relates positively to the likelihood of a firm engaging in product and process innovation, which supports the grease-the-wheel hypothesis in our sample of developing countries. Firms may prefer to pay bribes to public officials to overcome bureaucratic barriers and accelerate their innovative activities. Considering that our dataset was confined to developing countries, these positive relations may be explained by the fact that the presence of poor institutional conditions in developing countries makes innovating firms a victim of corruption. According to Ayyagari et al. (2014), innovating firms tend to pay higher bribes than non-innovating firms in countries where more bureaucratic procedures are required for initiating and operating a company and where there is a low quality of governance. Consequently, firms become involved in corruption to overcome bureaucratic nuisance and accelerate their innovative activities. Corruption can be said to function as a tax on innovators.

Our analysis revealed that bribery is positively associated with the probability of innovation activities of both foreign-owned and domestically owned firms. An explanation for this from the literature is that foreign firms are more innovative and have better access to external financing and therefore have a higher incentive to bribe than local firms (Blagojević & Damijan, 2013), However, as foreign-owned firms are financially less restricted (Girma et al., 2008), they can accommodate the costs of bribing more easily than domestic ones, especially in the context of

developing countries, where business dealings often include powerful foreign multinational firms with substantial leverage over local public officials (Carrington, 2010). Thus, foreign-owned firms may prefer to "get things done" in exchange for bribery. From the perspective of domestically owned firms, the mechanism would be slightly different. Domestically owned firms may feel less restricted than foreign ones in their interactions with local public officials in their home country because they are familiar with the culture of business–government relations and possible loopholes in legislation (Habiyaremye & Raymond, 2018). Hence, regardless of the firm ownership type, foreign-owned and domestically owned firms might appear to behave similarly, depending on the rules of the game in countries with poor institutions.

Although we find evidence that in developing countries with low R&D intensity bribery appears to facilitate innovation, it is important to stress that corruption has been clearly found to be a key factor of overall low innovativeness because it creates unfavorable infrastructural, poorer regulatory, and business environment. Hence, curbing corruption would be important step to boost innovation activities in developing countries with low R&D intensity and poor institutional quality.

In addition, in certain circumstances, corruption may generate competitive distortions and give a competitive advantage to specific firms (Campos et al., 2010). This positive association of corruption and firm innovation may persist as long as it serves the dominant monopolistic firms. Public officials could then keep receiving their monetary shares from their corrupt dealings. Hence, the findings of this study underscore the importance for developing countries of finding institutional and policy solutions to coordination failures where the company-level rational choice to bribe leads to market friction, negative externalities, and suboptimal development ay the macro level. A reasonable approach to addressing this issue could be to design more transparent and less bureaucratic governance so that firms would not have incentives to pay informal gifts or bribes to obtain what the firm needs for innovation activities. Furthermore, severe and discouraging penalties could be implemented when public officials demand informal gifts for performing their duties. Anti-corruption policies should be carefully designed and implemented with consideration of the diverse incentives of the counterparts of corruption.

This study is not without limitations. First, the weakness of relying on self-reporting as a data collection method is especially relevant when studying corruption. Since corruption is a hidden and illegal activity, a respondent may prefer to not reveal accurately what he/she has done in relation to questions concerning corruption. Survey designers have sought to minimize self-reporting concerns in corruption studies by asking respondents to speculate about other firms or individuals with similar characteristics (Jaakson et al., 2019). Respondents questioned in this way are expected to answer questions related to corruption more freely than if the questions are directed at them. However, additional research is needed to address the corruption–innovation nexus using less perception-based datasets. Moreover, this study included product and process innovations in empirical analysis, the future research, however, could extend the scope by including organizational and marketing innovations as part of innovation activities. Most importantly, one should interpret the results only in the context of developing economies that often witness highly corrupt environments, hence, generalizability might be limited. Future studies might address country heterogeneity aspects by covering a larger pool of countries and extend the observation period by incorporating new waves of the Enterprise Survey.

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APPENDIX

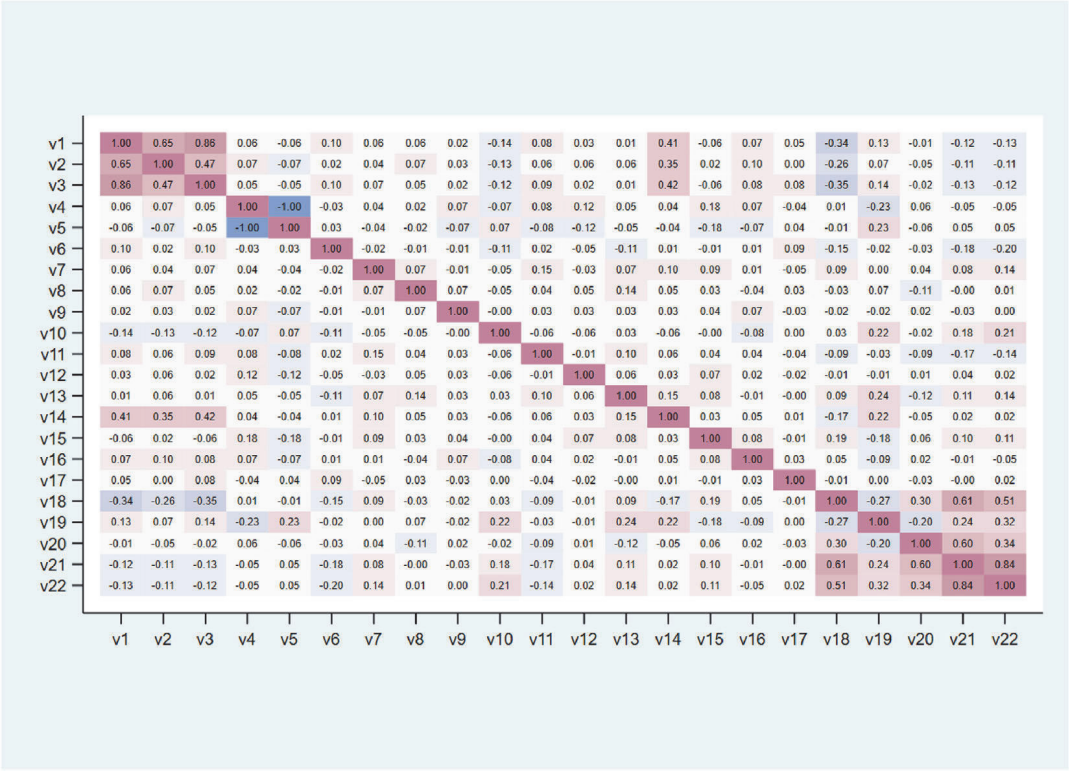

FIGURE A1 Correlation heatmap. *Notes*: Figure reports correlation coefficients. To save space, variable names have been replaced with v1, v2, …, v12. The corresponding variable names are: v1—*inno,* v2—*innoprod,* v3—*innoprocess,* v4—*foreign,* v5—*domestic*, v6—*bribe, v*7—*group*, v8—*age*, v9—*sales,* v10—*diversity,* v11—*employees,* v12—*skilled*, v13—*qualitycert*, v14—*R&D*, v15—*import license,* v16—*electric connect,* v17—*bureaucracy,* v18—GDP, v19—*population*, v20—*export*, v21—*innoindex*, and v22—*ruleoflaw*. *Source*: Compiled by authors. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE A1 List of countries with number of observations included in the analysis.

Country ISO3 code	Country name	Year	Observations	Foreign (%)	Domestic (%)
ARM	Armenia	2013	26	19	81
BDI	Burundi	2014	12	42	58
BGD	Bangladesh	2013	260	7	93
EGY	Egypt	2013	179	14	86
ETH	Ethiopia	2015	68	25	75
GEO	Georgia	2013	20	10	90
GHA	Ghana	2013	46	43	57
IDN	Indonesia	2015	146	50	50
IND	India	2014	1196	3	97
JOR	Jordan	2013	144	15	85
KAZ	Kazakhstan	2013	14	14	86
KEN	Kenya	2013	155	23	77
KGZ	Kyrgyzstan	2013	22	27	73
LBN	Lebanon	2013	163	4	96
MAR	Morocco	2013	65	17	83
MMR	Myanmar	2014	49	35	65
MNG	Mongolia	2013	12	25	75
MWI	Malawi	2014	23	52	48
MYS	Malaysia	2015	198	44	56
NAM	Namibia	2014	21	14	86
NGA	Nigeria	2014	147	23	77
NPL	Nepal	2013	40	10	90
PAK	Pakistan	2013	70	6	94
PHL	Philippines (the)	2015	168	50	50
SEN	Senegal	2014	33	39	61
TJK	Tajikistan	2013	7	29	71
TUN	Tunisia	2013	227	26	74
TUR	Turkey	2013	309	9	91
TZA	Tanzania, United Republic of	2013	47	15	85
UGA	Uganda	2013	45	49	51
UZB	Uzbekistan	2013	19	37	63
VNM	Viet Nam	2015	140	28	72
YEM	Yemen	2013	22	9	91
ZMB	Zambia	2013	35	51	49
Total			4128	18	82

Source: Compiled by the authors.

TABLE A2 Observations by sector.

Stratification sector	Foreign owned	Domestic owned	Total
Basic metals and metal products	65	1	**66**
Basic metals/fabricated metals/machinery and equipment	4	1	**5**
Chemicals and chemical products	187	52	**239**
Chemicals, plastics, and rubber	17	12	**29**
Construction	6	0	**6**
Electronics	8	18	**26**
Electronics and communications equipment	119	21	**140**
Fabricated metal products	135	16	**151**
Food	304	69	**373**
Furniture	18	4	**22**
Garments	327	96	**423**
Hospitality and tourism	1	0	**1**
Hotels and restaurants	37	1	**38**
IT and IT services	35	10	**45**
Leather products	48	5	**53**
Machinery and equipment	155	3	**158**
Manufacturing	198	52	**250**
Manufacturing panel	22	4	**26**
Motor vehicles	85	2	**87**
Motor vehicles and transport equipment	1	1	**2**
Nonmetallic mineral products	102	28	**130**
Other manufacturing	649	168	**817**
Other services	270	76	**346**
Other services panel	11	6	**17**
Printing and publishing	10	1	**11**
Retail	94	26	**120**
Retail panel	17	2	**19**
Rubber and plastics products	100	28	**128**
Services	2	1	**3**
Services of motor vehicles	5	2	**7**
Textiles	225	8	**233**
Textiles and garments	25	11	**36**
Transport	10	2	**12**
Transport, storage, and communications	35	0	**35**
Wholesale	14	0	**14**
Wholesale and retail	54	2	**56**
Wood products	4	0	**4**
Total	**3399**	**729**	**4128**

Source: Compiled by the authors.

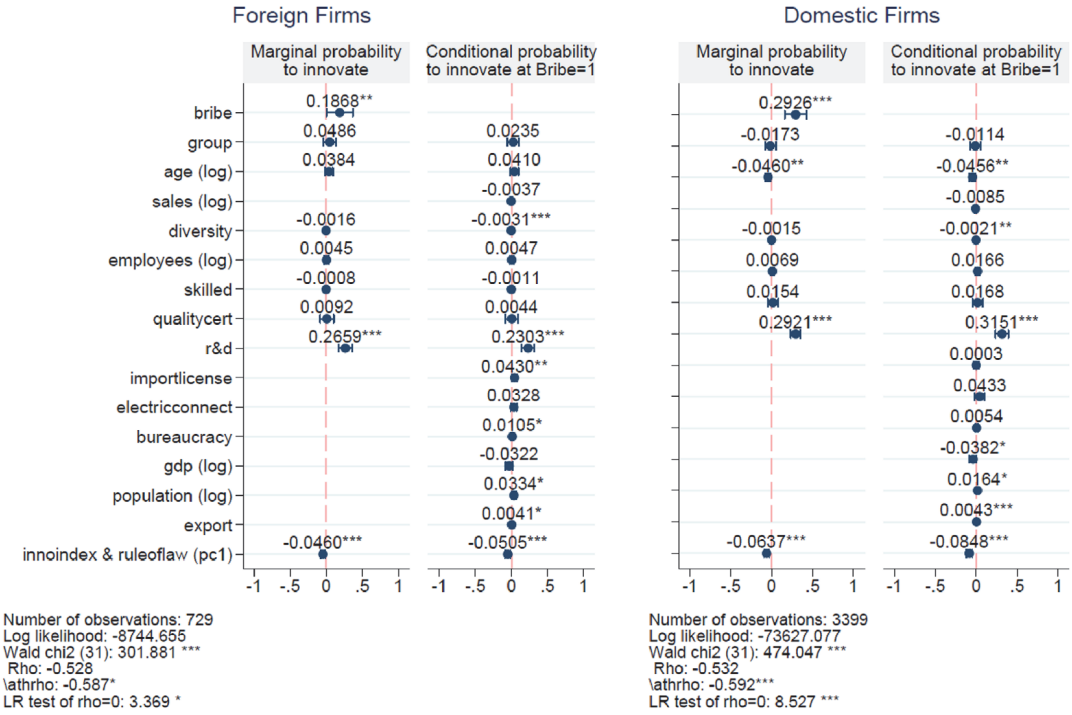

FIGURE A2 Marginal effects of the likelihood of a firm engaging in product innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE A3 List of variables.

Variable	Type	Description	Level	Source
Inno	Binary	The firm has engaged in product or process innovation (1)	Firm	ES
Innoprod	Binary	The firm has engaged in product innovation (1)	Firm	ES
Innoprocess	Binary	The firm has engaged in process innovation (1)	Firm	ES
Foreign	Binary	Foreign-owned firm (1). Firms are considered to be foreign owned if the majority ownership (≥10%) is owned by foreign individuals.	Firm	ES
Domestic	Binary	Domestically owned firms (1). Firms are considered to be domestically owned if the majority ownership (>90%) is owned by domestic individuals.	Firm	ES
Bribe	Binary	The firm has been asked for unofficial gifts of payments from government officials (1)	Firm	ES
Group	Binary	The firm is part of a larger establishment (1)	Firm	ES
Age	Continuous	Firm age calculated by subtracting the year the establishment began operations from the questionnaire year	Firm	ES
Sales	Continuous	Firms' annual sales revenues, converted to USD using year end closing exchange rates	Firm	ES
Diversity	Percentage	Percentage of sales generated by the firms' main product (product diversity indicator)	Firm	ES
Employees	Continuous	Number of employees	Firm	ES
Skilled	Percentage	Percentage of skilled employees with university degrees	Firm	ES
Qualitycert	Binary	The firm has obtained a quality certificate (1)	Firm	ES
R&D	Binary	Firm has invested in research and development (excluding market research)	Firm	ES
Import license	Binary	The firm has applied for import-related licenses (1)	Firm	ES
Electric connect	Binary	The firm has applied for electricity-related infrastructure connections (1)	Firm	ES
Bureaucracy	Ordinal	Tax administration as a firm self-perceived obstacle on a scale from 0 (no obstacle) to 4 (very severe obstacle)	Firm	ES
GDP	Percent	GDP per capita, PPP (current international $)	Cour	WB
Population	Continous	Total population	Country	WB
Export	Percent	Exports of goods and services (% of GDP)	Cour	WB
ruleoflaw	Continous	Estimated rule of law on scale −2.5 to 2.5	Country	WGI
Innoindex	Continous	Average of the input and output subindex scores	Cour	GII

Source: Compiled by the authors.

TABLE A4 Descriptive statistics.

	Foreign firms				Domestic firms			
	Count	Mean	Proportion (%)	SD	Count	Mean (%)	Proportion	SD
Inno	729		65.40			67.10		
Innoprod	729		47.20			46.50		
Innoprocess	729		58.60			60.60		
Foreign	729		100.00			0.00		
Domestic	729		0.00			100.00		
Bribe	390		13.30			16.90		
Group	729		44.20			37.20		
Age	729	21.35		15.12	22.58		15.88	22.58
Sales (mil)	729	301.48		5188.41	32.45		977.11	32.45
Diversity	729	83.88		22.73	88.38		19.63	88.38
Employees (th)	729	0.44		0.93	0.25		0.61	0.25
Skilled	557	11.10		6.93	10.01		5.06	10.01
Qualitycert	729		56.10			52.10		
R&D	729		32.50			35.90		
Import license	729		36.10			18.90		
Electric connect	729		14.00			9.10		
Bureaucracy	729	1.16		1.15	1.33		1.20	1.33
GDP *(th)*	729	9.67		7.53	8.30		5.82	8.30
pop (mil)	729	140.11		273.76	491.80		580.85	491.80
Export	729	35.86		21.39	29.68		16.85	29.68
ruleoflaw	729	−0.28		0.46	−0.29		0.41	−0.29
Innoindex	729	32.75		6.37	32.40		4.92	32.40

Source: Compiled by authors.

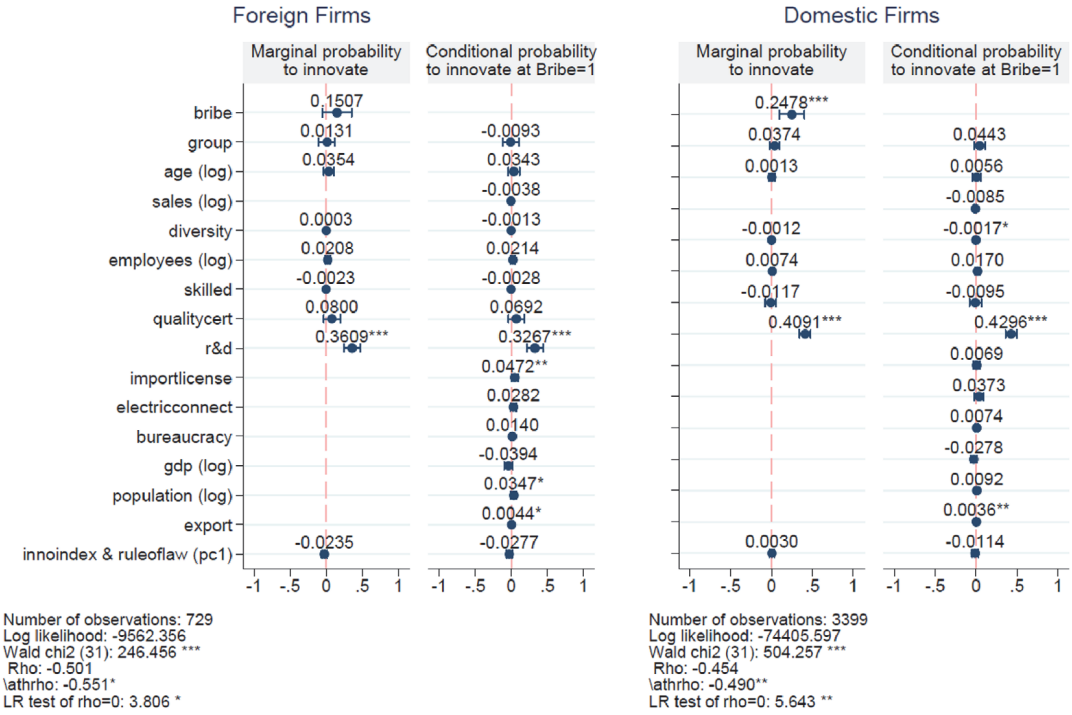

FIGURE A3 Marginal effects of the likelihood of a firm engaging in process innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

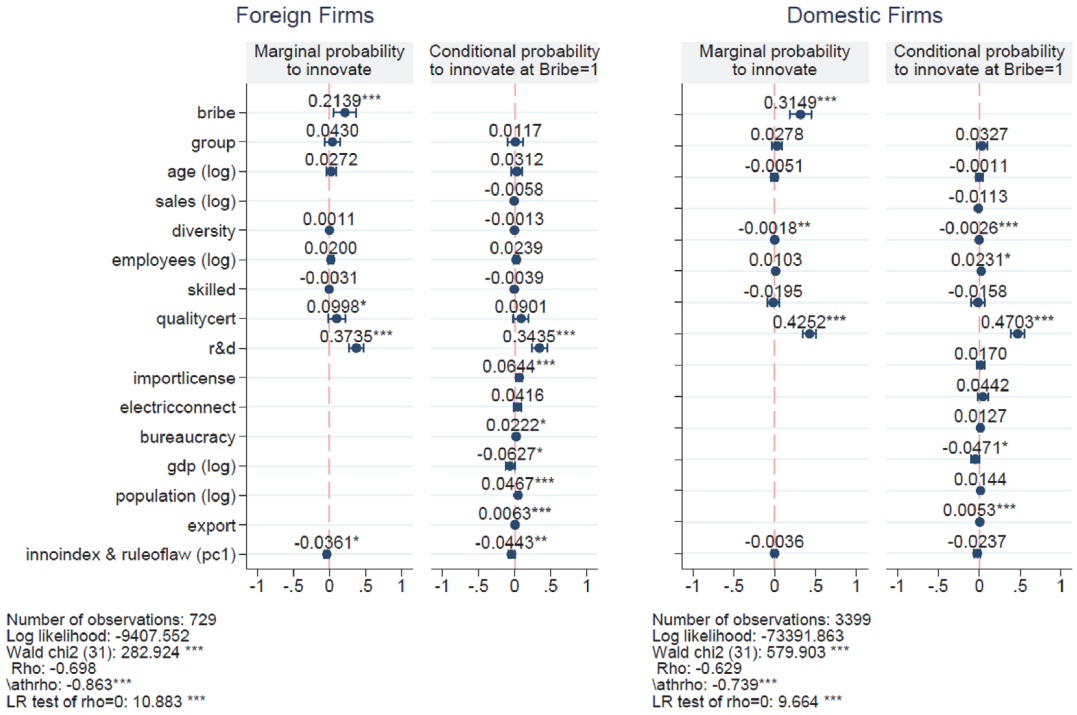

FIGURE A4 Marginal effects of the likelihood of a firm engaging in overall innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

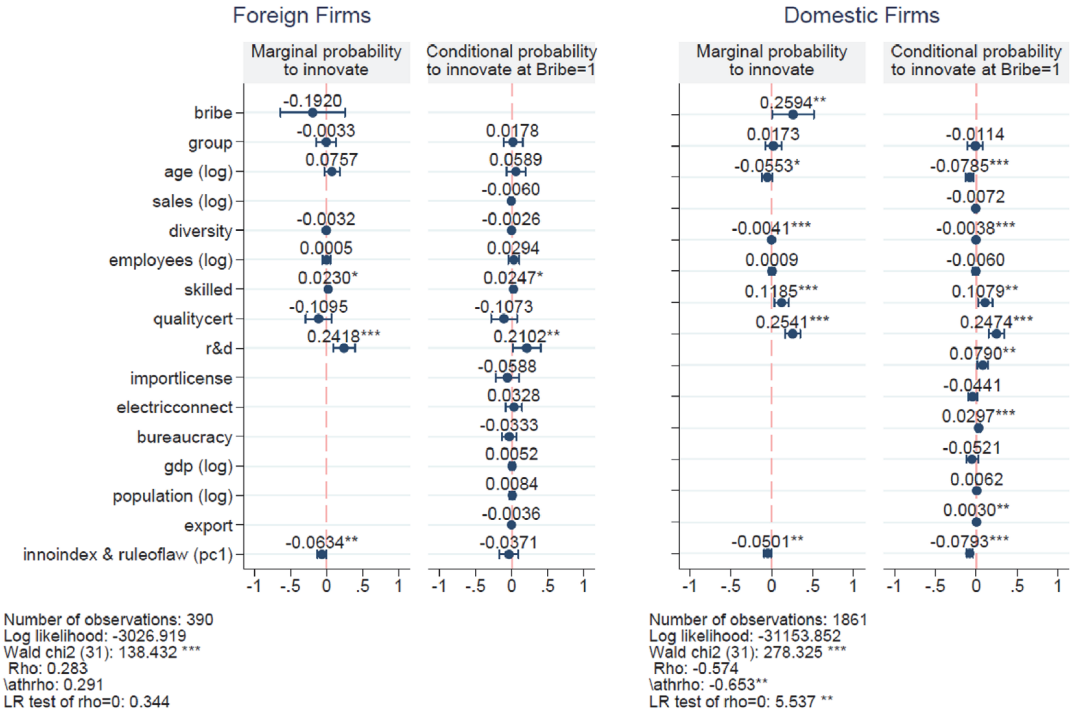

FIGURE A5 Marginal effects of the likelihood of a firm engaging in product innovation and bribery without imputing missing values for endogenous independent variable. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

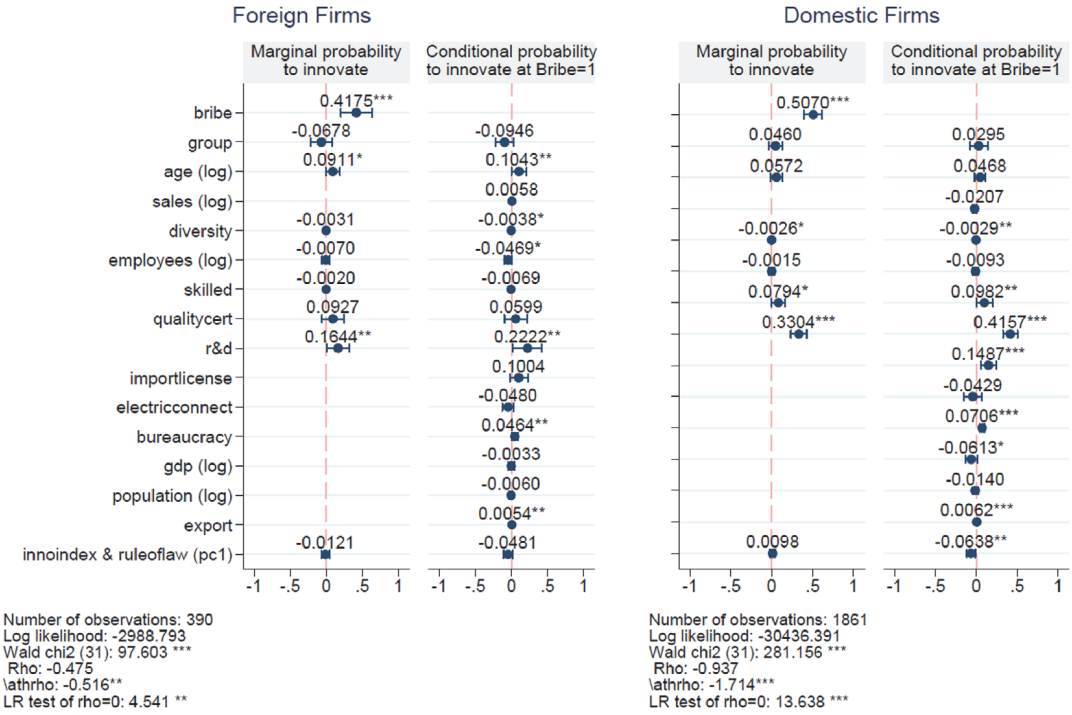

FIGURE A6 Marginal effects of the likelihood of a firm engaging in process innovation and bribery without imputing missing values for endogenous independent variable. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

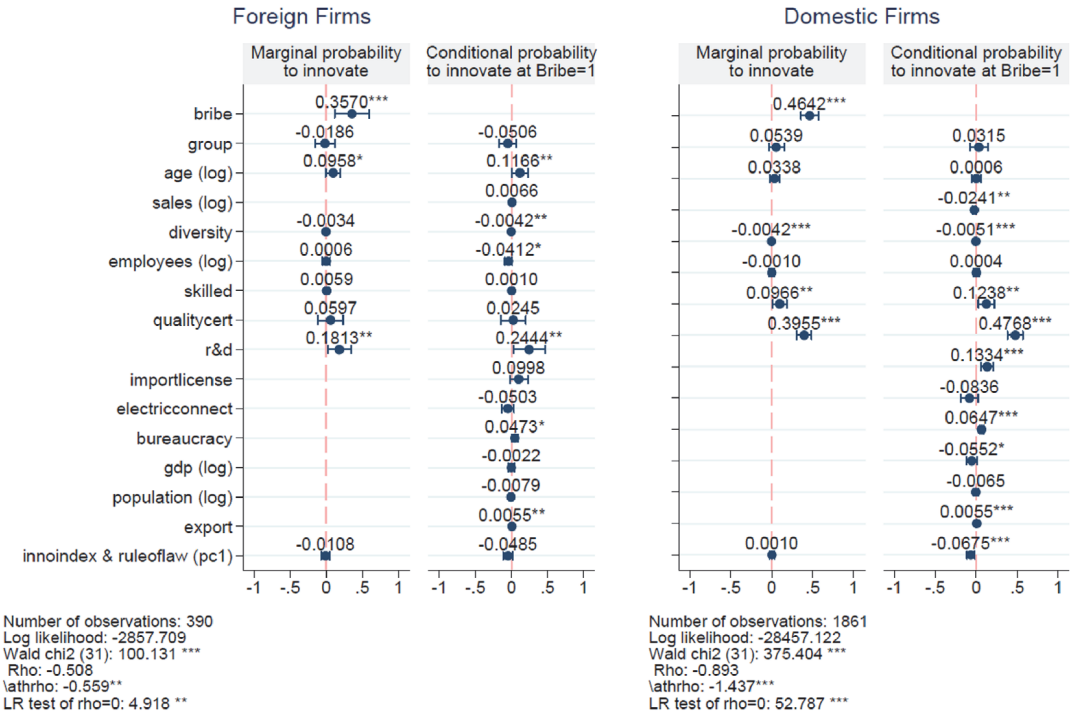

FIGURE A7 Marginal effects of the likelihood of a firm engaging in overall innovation and bribery without imputing missing values for endogenous endogenous independent variable. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

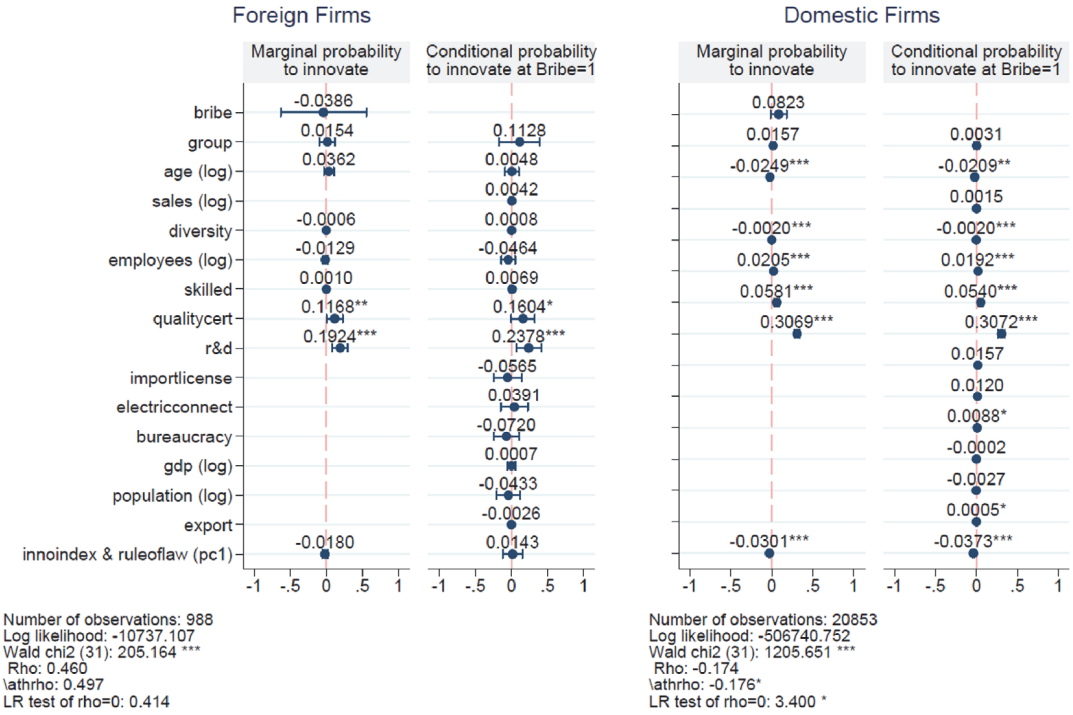

FIGURE A8 Marginal effects of the likelihood of a non-exporting firm engaging in product innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

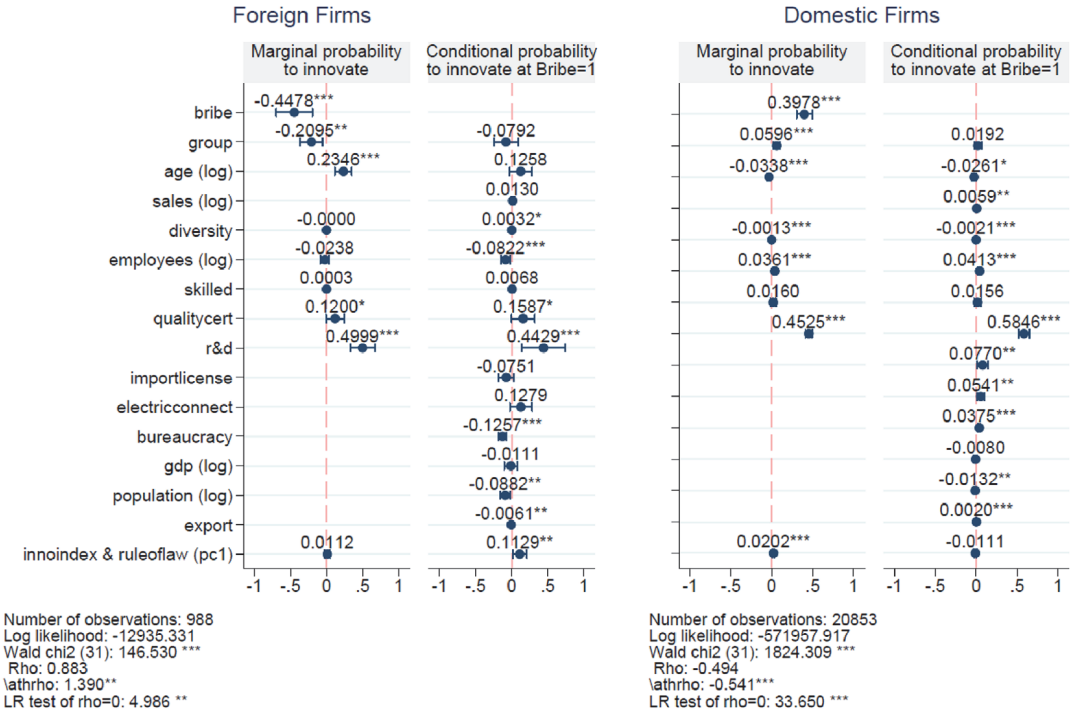

FIGURE A9 Marginal effects of the likelihood of a non-exporting firm engaging in process innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

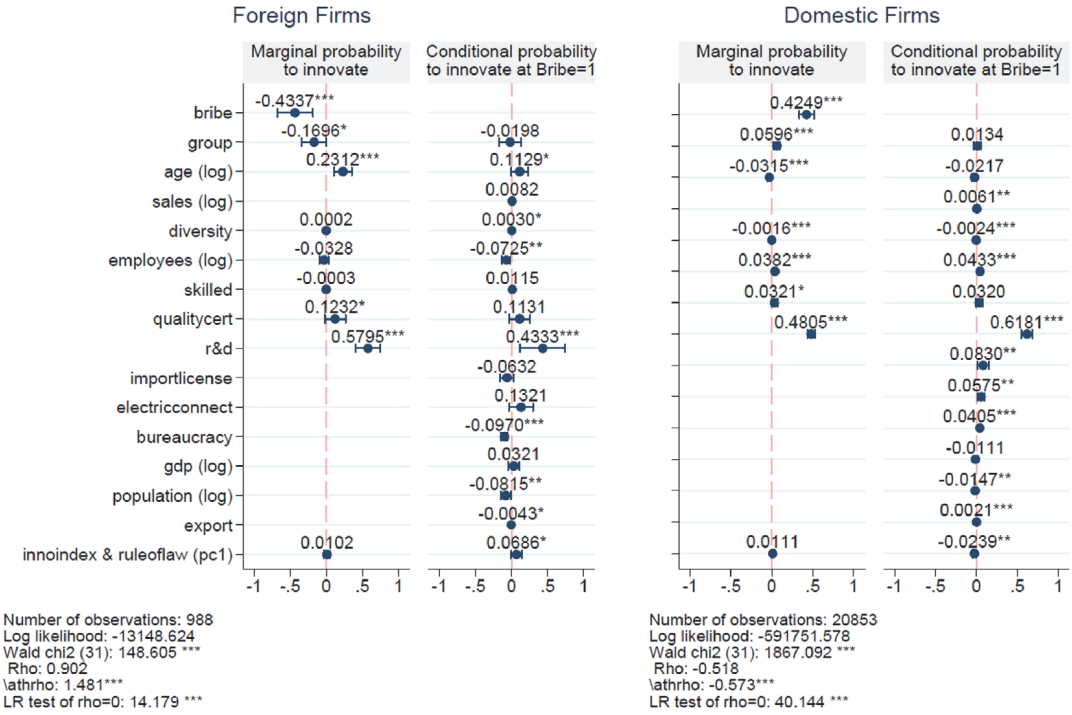

FIGURE A10 Marginal effects of the likelihood of a non-exporting firm engaging in overall innovation and bribery. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

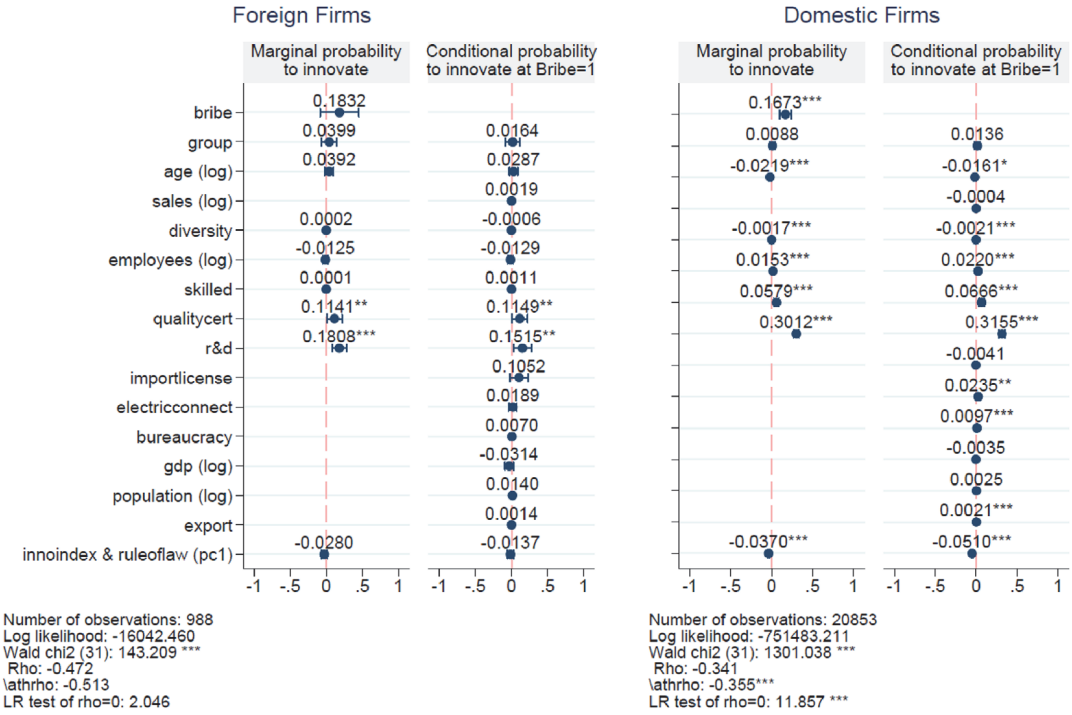

FIGURE A11 Marginal effects of the likelihood of a non-exporting firm engaging in product innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

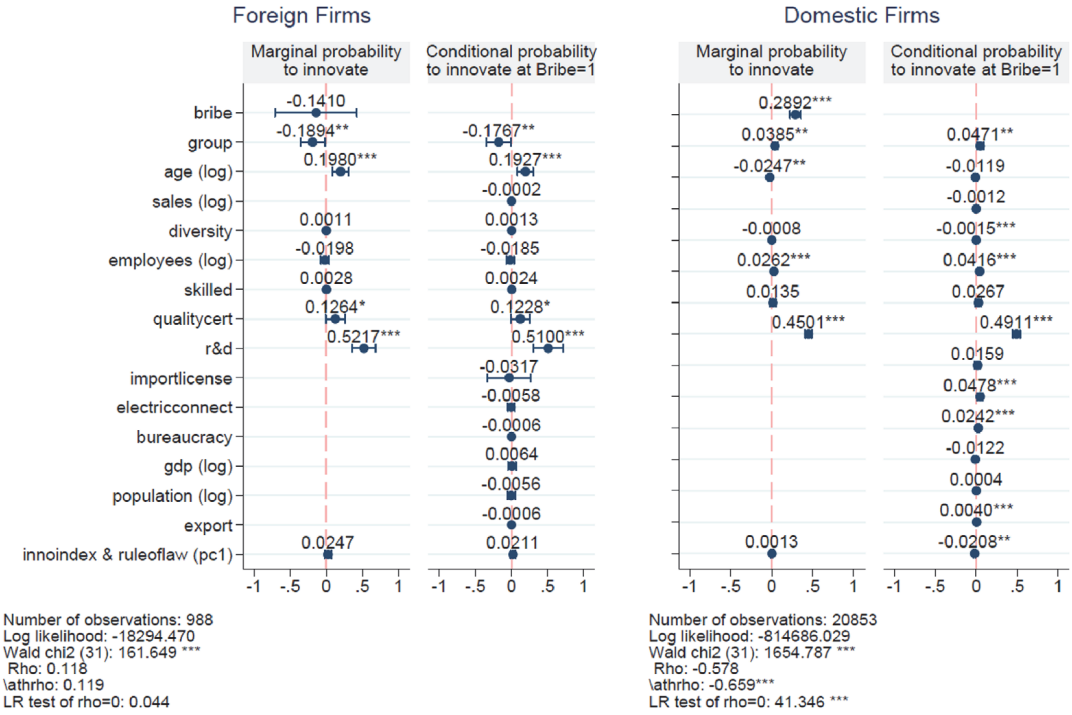

FIGURE A12 Marginal effects of the likelihood of a non-exporting firm engaging in process innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

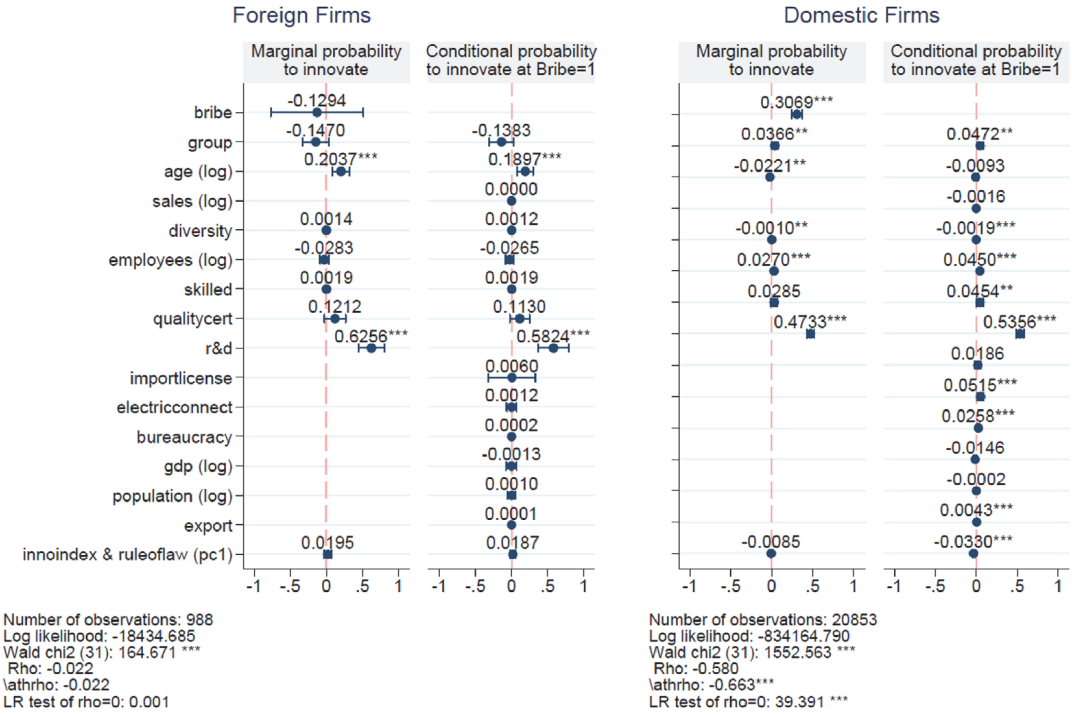

FIGURE A13 Marginal effects of the likelihood of a non-exporting firm engaging in overall innovation and paying bribe. *Notes*: Average marginal effects and unconditional method robust standard errors in parentheses. ***, **, * represent statistical significance on 1%, 5%, and 10% level accordingly. Sector, year, and vectorized country dummies are not reported. *Source*: Compiled by the authors. [Colour figure can be viewed at wileyonlinelibrary.com]

Appendix 4

HOW THE EU COHESION POLICY TARGETED AT R&D AND INNOVATION IMPACTS THE PRODUCTIVITY, EMPLOYMENT AND EXPORTS OF SMES IN ESTONIA

Publication IV

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How the EU Cohesion Policy targeted at R&D and innovation impacts the productivity, employment and exports of SMEs in Estonia

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ABSTRACT

The aim of this empirical investigation is to assess how the support targeted at R&D and innovation in the European Union Cohesion Policy Programme 2014–2020 affects the labour productivity, employment and exports of small and medium-sized companies. We estimate the treatment effects of two R&D financial support activities using a semiparametric efficient estimator with over-identified moment conditions and inverse probability weighting. The impact assessment uses population data on small and medium-sized enterprises in Estonia, the European Union member state that benefits most per capita from Cohesion Fund allocations. We found that support for R&D and innovation from the Cohesion Policy had a positive short-term effect on labour productivity and employment over the estimation period 2014–2018, and that the size and robustness of the effect were strongest for labour productivity. The short-term effect on exporting was ambiguous.

1. Introduction

The European Cohesion Policy Programme 2014–2020 is intended to reduce economic disparities and to foster social cohesion between the European Union (EU) member states by targeting those member states that have a gross national income (GNI) per capita that is less than 90% of the EU average.[1] The success of the Cohesion Policy (CP) in accelerating economic growth in member countries that are catching up economically hinges crucially on the viability of small and medium-sized enterprises[2] (SME) in these economies. SMEs comprise more than 99 % of businesses in Europe and provide about two thirds of jobs in the private sector.[3] One of the main objectives of CP in 2014–2020 is to make SMEs more competitive, particularly in research and innovation activity.[4]

How competitive SMEs are depends crucially on the productivity-enhancing investments in R&D and innovation (R&DI) that lay the ground for sustainable jobs and for competitive products and services. The main struggle that SMEs face in competitive markets is their limited size and the constraints on their access to capital and human resources (Kiss et al., 2018). The CP support that promotes R&D, innovation and exporting activities alleviates both these concerns, the capital constraints and the capacity restraints for human resource development.

The current research focuses on two activities under the CP priority axis that targets entrepreneurs capable of growth and supports their

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[1] Article 174 of the Treaty on the Functioning of the European Union. The Cohesion Fund 2014–2020 period concerns 15 member states: Bulgaria, Croatia, Cyprus, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia.

[2] The definition of SMEs corresponds to European Commission Regulation (EC) No 800/2008, which stipulates that the category of micro, small and medium-sized enterprises ('SMEs') is made up of enterprises which employ fewer than 250 people and which have an annual turnover not exceeding EUR 50 million, or an annual balance sheet total not exceeding EUR 43 million.

[3] https://ec.europa.eu/regional_policy/en/policy/themes/sme-competitiveness/.

[4] https://cohesiondata.ec.europa.eu/stories/s/n4ee-2h83.

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endeavours and activities in R&D, innovation and exporting, and that forges connections between SMEs and universities and research centres. The first of these activities is R&D clusters, which are aimed to increase the impact of the R&D system, and this supports R&D, innovation and technology collaboration, and cross-industry structures in growth areas with smart specialisations. The second is R&D vouchers, which target small and medium-sized companies in development areas to promote export activities and build managerial capacity. We estimate how effective the support from R&D clusters is by looking at 185 companies that received support, and the effect that R&D vouchers have by looking at 140 companies that benefit from them. The econometric analysis adopts a unique company-level dataset combined from eight different sources from the Estonian Ministry of Finance, Enterprise Estonia and Statistics Estonia. The new dataset allows us to control for the entire set of support activities funded from the European Regional Development Fund (ERDF) over the 2014–2020 programme period and over the previous programme period 2007–2013. We control for the potential selection and outcome biases that may arise from recurrent support activities, and additionally account for the national subsidies allocated by Enterprise Estonia. Controlling for an entire complex system of different support schemes and the overlaps between them lets us identify how a particular support measure activity impacts productivity, employment and exports, which are the strategic objectives stipulated by the European Union Cohesion Policy for Estonia in the current 2014–2020 support period. Depending on the model specification, the analysis controls for 12–14 confounding variables.

The number of studies that estimate how national or European grants affect the performance of SMEs is broad and expanding (see the recent literature survey by Dvouletý et al., 2020), but our research contributes in multiple respects. We employ population data on Estonian companies and control for a wide range of confounding variables, we use a recently proposed efficient treatment effects estimator by Cattaneo (2010) and Cattaneo et al. (2013) and, as a robustness check we additionally use the marginal mean weighting through stratification (MMWS) adjustment, which is a probability weighting adjustment technique by Linden (2017) that provides consistent weights when the weight estimates - based on propensity scores - are flawed because of a functional misspecification in the estimation process.

We followed the criteria of the support measures closely in forming the treatment and control groups, and we consulted with the public sector experts responsible for administering the European structural funds to get the information needed to set up adequate counterfactuals and to define the controls needed for the confounders. The observation period of the study, 2014–2018, featured steady and solid economic growth, low unemployment and modest inflation (see Table A1 in Appendix A). The stable economic environment of our observation period means our results are largely undistorted by macroeconomic volatilities, or sudden shocks and their correction mechanisms, which might otherwise have biased the estimates of the treatment effects even with annual dummy controls. Finally, we seek evidence from Estonia, the member country that received the highest allocation per capita from the Cohesion Fund Programme in 2014–2020.[5] We believe that the effects of the support are most identifiable when allocation intensity is high. Our results show that CP support affects labour productivity, employment growth and exports quite differently, with the strongest short-term effect for productivity and the weakest outcome for exports. There is also a notable difference between the R&D clusters and R&D voucher support. The vouchers have a significant but different in size impact on productivity, employment and export outcomes, whereas the support from R&D clusters has a substantial and significant positive effect on productivity alone. The rest of the paper proceeds as follows. Section 2 reviews the literature on policy evaluation and impact assessment for public grants, and also surveys research on the innovation, R&D and exporting activities of SMEs. Section 3 presents the data, explains the principles for forming the sample, and describes the variables. Section 4 sets forth the estimation strategy, presents the estimators, and clarifies the methodological issues. Section 5 reports and discusses the results. Section 5 points out the lessons learned and Section 7 concludes.

2. Literature review

The central aim of Cohesion Policy is to reduce economic and social disparities between European Union regions while supporting the competitiveness of SMEs by encouraging research and innovation activity.[6] The question of whether CP serves its central objectives and leads to convergence across Europe has concerned policy makers and economists alike. The plentiful and growing research on the economic impact of European Structural and Investment Funds (ESIF) has, however, reached varying and even contradictory results (see e.g. Dall'Erba & Fang, 2017; Dall'Erba & Le Gallo, 2008; Hagen & Mohl, 2011; Pienkowski & Berkowitz, 2016; Ramajo et al., 2008). For a comprehensive summary, see Appendix B.

A successful R&D and innovation policy counteracts the market failure of information asymmetry, the imperfections in capital markets, and the incomplete appropriability of R&DI returns that would otherwise leave productivity-enhancing investments below their optimal level. Bachtrögler et al. (2020) claim that one of the reasons results on the impact of Cohesion Policy have been ambiguous lies in their two-dimensional heterogeneity. The first dimension of heterogeneity arises because the set of public support schemes that aim at varying outcomes and apply varying eligibility criteria for beneficiaries is highly diversified (Fattorini et al., 2020; Rodríguez-Pose & Fratesi, 2004). Heterogeneities in outcomes that arise from differences in the types of SME funding programme and support have also been reported by Potluka et al. (2010) and Reinowski and Schultz (2006). The second dimension of heterogeneity arises from the regional diversities in the regulatory implementation of support schemes, and most importantly from differences between regions in their economic environments and dynamics and in their entrepreneurship ecosystems (Bachtler et al., 2014; Becker et al., 2013; Cappelen et al., 2003; Ederveen et al., 2006; Farole et al., 2011).

Ramajo et al. (2008) investigated the regional heterogeneity dimension of Cohesion Policy in 163 NUTS-2 regions from 12 European Union countries in 1981–1996. Their study confirmed that regions in countries that implemented the Cohesion Policy had a higher conditional rate of convergence for GDP per capita. Becker et al. (2010) considered NUTS-2 and NUTS-3 at the regional level and found that Cohesion Policy had a positive effect on a region's GDP per capita, but not on employment. Dall'Erba and Le Gallo (2008) present the opposite result on 145 NUTS-2 regions and claim that no regional convergence arises from Cohesion Policy since there are no considerable cross-border spillovers from public investments. Esposti and Bussoletti (2008) and Falk and Sinabell (2008) corroborate this, finding that the effect of Cohesion Policy on cross-regional convergence among NUTS-2 regions in Europe was negligible.

Fattorini et al. (2020) and Rodríguez-Pose and Fratesi (2004) studied the heterogeneity in Cohesion Policy support schemes along the priority axes and found that support schemes that foster human capital and R&D and those that target a more productive segment of enterprises have the

[5] https://epthinktank.eu/2016/10/10/eprs-and-the-2016-european-week-of-regions-and-cities/the-cf-allocation-per-member-state/.

[6] We are not treating R&D and innovation as completely distinctive categories, since R&D is a central input of innovation while innovations engender new research and knowledge and the support measures under investigation address both R&D and innovation, or R&DI. There is abundant evidence in the empirical literature for a strong link between R&D and innovation, see for example Bronzini and Piselli (2016), Hottenrott et al. (2017), among others.

highest impact. Lafuente et al. (2020) stress the different productivity outcomes that result from policies supporting either Kirznerian or Schumpeterian entrepreneurship. Kirznerian is associated with increased business formation and higher employment, but may expand the share of low value added businesses, while Schumpeterian entrepreneurship by contrast introduces radical innovations that boost productivity but cause disruption to existing businesses and displacement of jobs. Hence the Cohesion Policy outcomes for productivity, employment and exports are strongly dependent on the underlying priorities of entrepreneurship policy, and whether it targets radical innovation in line with the Schumpeterian approach or expansionary and incremental innovation as in the Kirznerian approach.

The bulk of CP funding benefits SMEs directly or indirectly. The industrial policy arguments in favour of public support programmes for SMEs rest on the rationale of market failure. Their limited size means that SMEs cannot diversify their innovation portfolios much and this makes their innovation returns vulnerable to uncertainty. Furthermore, the capacity of SMEs to implement a policy of intellectual property protection may be weaker, and this may restrain the appropriability of their innovation returns (Arrow, 1962) and make their innovations vulnerable to imitation by competitors. In consequence SMEs might underinvest in innovation without the support of public grants, and this underinvestment could result in them losing opportunities to deploy new technologies, penetrate new markets and create new jobs (Acs & Audretsch, 1990). The main challenge for public support programmes that promote innovation and R&D by SMEs is how to achieve short-term measurable gains for the performance of beneficiaries and not merely the long-term structural effects that might not promote entrepreneurial incentives to innovate (Hottenrott et al., 2017).

Freel et al. (2019) employ a matching method to show that public grants for R&DI have positive effects for German SMEs. An earlier study by Liu and Rammer (2016), which also focused on German SMEs, finds that public innovation funding programmes lead to increased innovation output for both product and process innovation. They find however a difference in whether the innovation support promotes cutting-edge technology and new-to-market innovations or only new-to-the-firm innovations, and that only the new innovation is associated with subsequent export success. Czarnitzki and Lopes Bento (2013) study the effects of public grants on R&D investment and employment in the Flanders region and report a positive effect on both outcomes. Value added, employment or exports only increase in response to public R&DI support that encourages additional private R&DI activity and does not merely replace it or crowd it out. Aerts and Schmidt (2008) test whether public R&D subsidies crowd out private R&D investment in Flanders and Germany, and they reject the crowding-out hypothesis and conclude that the firms that are funded are significantly more active in R&D than those that are not funded. The meta-regression findings of Dimos and Pugh (2016) that control for publication selection bias and for a wide range of sample and study heterogeneities similarly reject the crowding-out hypothesis, but find no substantial evidence for additionality effects. Gustafsson et al. (2020) apply logistic and count data models to data from Swedish companies and show a significant adverse selection of companies with lower productivity into innovation subsidies.

Foreman-Peck (2013) takes a sample of 10,000 SMEs operating in the United Kingdom and uses propensity score matching to show that public support has been both effective and efficient in boosting the innovation of companies, but that the innovation outcomes were substantially stronger for SMEs that had a focused internal innovation strategy. In Finland, Koski and Pajarinen (2013) show positive evidence for the impact that public subsidies have on employment at start-ups and at established firms that have been in business for more than five years. Not all studies confirm a positive effect from public support for innovation however. Czarnitzki et al. (2011) studied the impact of the Cohesion Policy innovation scheme on the inputs and output of innovation at firms operating in Germany, France and Czechia. They found that after they controlled for national public grants, support from Cohesion Policy did not have an effect on the innovative activities of firms. The follow-up study by Czarnitzki and Lopes-Bento (2014) updated this with the opposing result that showed Cohesion Policy support had a positive impact on innovation, and that when Cohesion Policy support was complementary to national public grants the highest innovation effect was felt at firms that benefited from both national grants and Cohesion Fund support schemes.

Benkovskis et al. (2018) look at a sample of firms in Latvia and report that the ERDF has immediate positive benefits on the employment, turnover and capital stock of firms, and three-year lagged positive effects on productivity. The study does not find that ERDF support has any larger effect on productivity than private funding does, but it confirms that ERDF beneficiaries had a larger increase in employment than recipients of private funds did. The findings also showed that the productivity gains were larger for ERDF participants that initially had lower productivity and capital intensity, but higher leverage and more employees. Bachtrögler and Hammer (2018) adopt propensity score matching techniques and conclude that Cohesion Policy support has mixed effects on the performance of manufacturing firms, except for a significant and positive effect on employment. On a similar note, Bondonio and Greenbaum (2014, 2006) show from firm-level data from Northern and Central Italian regions that ERDF fund allocations mainly had a positive effect on employment growth and that there was no significant difference between the ERDF co-funded programmes and national or regional programmes in this effect.

Čadil et al. (2017) present evidence on SMEs in Czechia and find that Cohesion Policy support from the 2007–2013 programme had a positive impact on personnel expenditures, but no effect on value added. Mouqué (2012) also reports limited productivity effects but significant employment effects from innovation support. Criscuolo et al. (2019) propose that there may be a trade-off between the positive employment effect and productivity, since public support may lead to less productive workers being hired. Colombo et al. (2011) find that only selective R&D subsidies, allocated on a competitive basis, increased the total factor productivity of high-tech start-ups that received them, while nonselective or automatic subsidies had no effect. A further aim of public funding is to support the exporting capacity of SMEs and their expansion into foreign markets (Love & Roper, 2015), both of which translate into economies of scale and job creation. Görg et al. (2008) do not, however, find strong evidence for public grants having a direct effect in promoting exports, but find rather an indirect positive productivity effect. Srhoj and Walde (2020) use a difference-in-difference estimation on Croatian companies over 2009–2014 and find that export grants have a positive effect on the introduction of new or existing products to foreign markets with additionality effects for value added but not for employment.

As these results are inconclusive, there is room for further studies that could cast light on the short and long-term effects of public R&DI support programmes on the performance of companies in areas such as employment, productivity and exporting.

2.1. Targeted R&DI support from Cohesion Policy in Estonia

According to the European Semester country reports 2019, the main challenge for growth in Estonia is the insufficient progress in raising labour productivity given the ageing population and the natural decline in the number of people of working age.[7] Positive net immigration, mostly from third countries, has not fully counterbalanced the gap in demand for labour, especially skilled labour, and the country has witnessed substantial wage growth in recent years. One of the main policy objectives for tackling the demographic trends that impede growth has been to increase productivity-enhancing investments in R&DI, including

[7] https://ec.europa.eu/info/publications/2019-european-semester-country-reports_en.

Table 1
Institutional setting for the Cohesion Policy Funds R&D activities.

Cohesion Policy priority axis 4: entrepreneurship growth strategy with R&DI activities	
Activity	Measure
Activity 4.2.4: State-funded cooperation structures, e.g. for clusters and technology development centres *Eligibility*: Expenses related to development of clusters, including expenses on technology and market research, cross-cluster product or process developments, training and education of staff, cluster-wide marketing activities, increasing international visibility etc.	4.2: Increasing the regional socioeconomic impact of the R&D system and smart specialisation to develop growth areas (ICT + health + resources) *Targets*: Number of enterprises operating in smart specialization areas Number of partners involved in R&DI cluster
Activity 4.4.2: Research and development activity voucher *Eligibility:* Expenses that relate to product or process innovation including consultations, product tests and industrial experiments, feasibility and cost-benefit analysis, patent or certification related legal consultations and registrations fees, development and implementation of technological solutions.	4.4: Entrepreneur's development plan support measure to facilitate development of companies and their export activities and improve their management capacities *Targets:* Private state-subsidised investments into R&DI Number of enterprises with granted R&DIvoucher

Source: Compiled by the authors based on the legal requirements: Conditions and procedures for supporting the development of clusters RT I, 20.05.2015, 3; Structural Assistance Act RT I, 21.06.2014, 1 and Conditions and procedure for granting support for innovation and development units RT I, 13.11.2015, 3; Structural Assistance Act RT I, 21.06.2014, 1.

investments in automation and digitalisation and in training labour.

SMEs have a pivotal role in the Estonian economy. SMEs in the non-financial business sector provide more than 75 % of employment and value added in the country, while such businesses provide 66.6 % of employment and 56.4 % of value added in the EU28 (European Commission, 2019). Though the number of start-ups in Estonia is the highest in the EU, the share of SMEs that engaged in some innovation activity in 2014–2016 was below the EU average.[8] With just 1.3 million inhabitants and a history of political and economic transition, Estonia is the member state that benefits most from European CP funds per capita (Fig. A1 in Appendix A). The European funds play a substantial role in public sector R&D expenditures, and Estonia is one of the most successful participants in the Horizon2020 programme, with the proportion of funds awarded to GDP exceeding the European Union average 2.6 times.[9]

Nevertheless, gross domestic expenditure on R&D in Estonia has declined since 2012. R&D expenditure in Estonia was 2.3 % of GDP in 2011, but this had dropped to 1.4 % by 2018, a level that is substantially below the European Union average of 2.06 % in 2017, and far from the strategic target of 3 % R&D intensity by 2020. The total planned support from the R&DI clusters (activity 4.2.4) for the entire 2014–2020 programme period was about 100 million euros, of which EU sources cover 51 %. The corresponding total planned support from the R&D voucher activity (4.4.2) was about 10 million euros. The ultimate policy targets of R&DI policy are to improve the productivity of companies, create new jobs, and strengthen exporting capacity and competitiveness in global markets.

The support activities targeted at R&DI fall under the Estonian Operation Programme as part of the CP priority axis 4, which is designed to build the capacity to grow of enterprises with R&DI activities. The R&DI activities that foresee particular support schemes and types, such as financial or non-financial support, along with support channels and eligible beneficiaries belong under measures that target specific policies as set out by the policy priority axes. The main policy aims of measures governing the R&D activities are the increase in the private sector R&D to GDP ratio and the higher share of enterprises that are involved in R&DI collaboration with universities or other R&D institutions. The current study focuses on two financial support activities (see Table 1). The activity 4.2.4 supports R&D and technology clusters and development centres and belongs under measure 4.2 that is intended to increase the regional socioeconomic impact of the R&D system and smart specialisation.[10] The activity 4.4.2 grants research and development activity vouchers and it belongs under measure 4.4 that targets development of companies and their export activities and improvement of their managerial capacities through research and development activity.

Our study is not the first to evaluate the effect of public grants on the performance of companies in Estonia. Vildo and Masso (2009) assess the impact that public start-up grants had on the employment, sales, capitalisation and survival rate of companies in 2002–2003. Their propensity score matching with the kernel and nearest neighbour method proved a positive effect of 21–25 % on employment and 31–44 % on sales within 2–3 years from treatment, whereas a positive effect on productivity shown in value added per employee arose only in the third year from treatment and ranged between 53 % and 71 % depending on the matching method used. Hartšenko and Sauga (2012) use a difference-in-difference estimator and investigate the impact of R&D, technology and export-oriented grants on the net sales of companies over the period 2004–2010. Their study concluded that R&D grants increased net sales by about 20%, technology grants did so by 33 %, and export grants by 11 %.

A propensity score matching technique was used for the mid-term appraisal of Entrepreneurship and Innovation policy in Estonia for the programme period 2007–2014 (Enterprise Estonia and Ministry of Economic Affairs and Communications, 2014;[11] Vicente & Kitsing, 2015), which compared the outcomes for the treated, or beneficiary, companies and the untreated, or non-beneficiary, companies in value added, return on sales, number of employees, and business revenues. The matching procedure used information from before the treatment on multiple company-level variables including economic activity, location, number of employees, turnover, export sales revenues, years in operation, labour costs per employee, profitability, and assets. The selection into treatment had a positive association with the number of employees, export status and profitability, but a negative association with the company's age shown as years in operation. The analysis revealed considerable heterogeneity in the results across different grant types.[12] In general, however, the employment, sales and profitability indicators of companies that received a grant improved significantly relative to those of the control group. There was, however, no firm evidence that the grants had positive outcomes for exports or value added, and the export sales per employee of the control group in fact exceeded those of the treatment group. The effect of the grants on value added per employee was also intriguing, with some negative estimates across grant types, which Vicente and Kitsing (2015) argue might be related to certain practices in earnings management or might be just the counter reflection of a positive effect on employment or an effect of temporary excess employee capacity.

[8] In the EU 49.5% of SMEs were engaged in some innovative activity in 2014–2016, while in Estonia 46.6 % were (European Commission, 2019).

[9] https://www.etag.ee/wp-content/uploads/2019/04/Estonian_Research_2019_veeb.pdf.

[10] The support activity 4.2. on clusters and technology centres benefits not only commercial entities, but also public universities and research centres, in which case the effect on the productivity, employment or exports of companies is indirect and stems from the positive spillovers.

[11] https://www.eas.ee/images/doc/sihtasutusest/uuringud/ettevotlus/ettevotlustoetuste-vahehindamine-2014.pdf.

[12] The analysis considered multiple types of grants including grants for start-ups, scale-ups, upskilling, exporting, innovation or technology investments.

Table 2
Number of treated and counterfactual in the final estimation sample.

Support activities	R&D clusters	R&D vouchers
Treated $D_{d=1}$	187	143
Control $D_{d=0}$	10,092	8574

Source: Author's own calculations.

The evidence from the evaluation of public support in less mature markets or in transition and post-transition economies is still limited and mostly recent (Benkovskis et al., 2018; Čadil et al. 2017), and is that R&DI investments in these economies are particularly vulnerable to market failure because of limited external resources, and are very challenging for their SME-dominated business sectors because of limited internal resources. Maroshegyi and Nagy (2010) use evidence from Hungary and, like Hartšenko and Sauga (2012), they find that public or EU-funded grants had a positive effect on the sales of companies. Benkovskis et al. (2018) uses Latvian data and Čadil et al. (2017) employ evidence from Czechia however, and report conflicting evidence for the effects of public support policy on the productivity of companies, though their results broadly agree that there are positive effects on employment. Given the inconclusive evidence from the literature evaluating public support, particularly for the member states that have more recently joined the common market, our study contributes both in context and in the methodological scrutiny described in the next section.

3. Data sources, variables, and the principles of sample formation

3.1. Data sources

This study uses a unique dataset that combines multiple sources of information and that specifically serves the purposes of estimating how the CP ERDF support affects the productivity, employment and export outcomes of firms.[13] The Estonian Ministry of Finance provided the data on support for the current CP programme period 2014–2020 and the previous one 2007–2013, along with information on all the individual projects and beneficiary companies funded by the ERDF.[14] In addition, Enterprise Estonia, a governmental body that allocates national support for developing the competitiveness, smart specialisation[15] and export capacity of Estonian enterprises provided data on the amount received by companies from national support schemes over the treatment period 2014–2018. This meant we could control for the confounding that stemmed from the treatment in the previous CP funding period in 2007–2013 and from the national support schemes, while also running numerous controls from the recent CP period of main interest for observations from 2014 to 2018. These controls used registry data on Estonian companies that represent the entire population of companies in Estonia and that cover business demography information including company size, age, ownership, sector and location, financial and accounting information, and the record in exporting.[16]

3.2. Principles for forming the analysis population and estimation samples

The data that identify how the CP funds impact the productivity, employment and exports of companies are a company-year panel of a population of Estonian commercial enterprises that are either private limited companies, public limited companies or commercial associations.[17] An indicator variable separates public and private limited companies as there is a tenfold difference in the minimum capital requirements imposed by national legislation.[18]

We conducted the impact assessment on the level of activity with separately formed treatment and control groups for both activities, 4.2.4 R&D clusters, and 4.4.2. R&D vouchers. The control groups were formed by following closely the eligibility criteria of the corresponding support activity to meet the condition of common support in estimating the impact of the treatment. In addition, the pre-estimation analysis cleaned outliers from the control groups using both univariate and multivariate methods. The univariate approach removed companies from the control group if their corresponding variables were more extreme than the minimum and maximum values of the treatment group.[19] Since the univariate cleaning procedure does not account for abnormalities in data patterns, we also used the BACON approach of blocked adaptive computationally efficient outlier nominators, as proposed by Billor et al. (2000), to remove control group observations with atypical data patterns. We believe that our principles for forming the control group using qualitative eligibility criteria and quantitative univariate and multivariate data cleaning procedures set reliable boundaries for common support.

To remove the noise of the confounding effect that stems from parallel treatment we removed from the control group all the companies that benefitted from CP ERDF support under any other support activities during the treatment period. This removal did not extend to those companies that received support from the previous 2007–2013 funding period, nor to those companies that had received entrepreneurship support from national public grants. Instead, the effects of national public grants and the previous European funding grants from 2007 to 2013 were taken into account by the introduction of covariates for them in the treatment estimations and the application of the selection-on-observables condition (Cattaneo et al., 2013). The final, cleaned sample for analysis comprises 10,279 and 8717 observations for the two R&DI support activities as presented in Table 2.

3.3. Principles for forming the analysis population and estimation samples

We evaluate how CP ERDF impacts the labour productivity, employment and export outcomes of Estonian SMEs using a broad set of controls for confounders. Our selection of observables follows a large

[13] Cohesion Policy funds for achieving the strategic objectives of the current support period, set in the national reform programme Estonia2020 and based on the general strategic objectives of Europe2020.

[14] The dataset separates final beneficiaries from those receiving support who intermediate funds for final use, and this lets us identify the final beneficiaries as the ultimate subjects of interest for our study.

[15] Espenberg et al. (2018).

[16] Statistics Estonia merged the sub-datasets and generated the underlying combined company-level database with pseudo-anonymised company identifiers for confidentiality purposes. The dataset is not public and is only accessible for authorised researchers through the Statistics Estonia secure scientific data-analysis environment.

[17] The study considered profit-maximising entities only, since the support impact assessment relies on profit-maximising incentives that drive productivity, employment and export outcomes. Hence the study did not consider non-profit organisations or government organisations.

[18] Under the Estonian Commercial Code (RT I, 10.07.2020, 35) the minimum share capital requirement for a public limited company is €25,000 (§ 222) and for private limited companies it is €2500 (§ 136). The minimum share capital requirement for commercial associations is €2500 (§ 1[3]) under the Commercial Associations Act (RT I 2002, 3, 6).

[19] The data cleaning procedure, which used additional information on the application level funded, reclassified the NACE activity of 25 companies in the treatment group.

Table 3
Smart specialisation by support activities and treatment status.

	R&D clusters		R&D vouchers	
Smart specialisation	YES	NO	YES	NO
$D_{d=1}$	116	71	45	98
$D_{d=0}$	905	9187	843	7731

Source: Author's own calculations.

Table 4
Programme period 2007–2013 support by activity type and 2014–2018 treatment status.

		R&D clusters		R&D vouchers	
CP 2007–2013		YES	NO	YES	NO
CP	$D_{d=1}$	93	94	40	103
2014–2018	$D_{d=0}$	562	9530	575	7999

Source: Author's own calculations.

Table 5
Sample companies by treatment status and NACE2 economic activity.

	R&D clusters		R&D vouchers	
	$D_{d=1}$	$D_{d=0}$	$D_{d=1}$	$D_{d=0}$
A- Agriculture, forestry and fishing	7	96	-	-
C- Manufacturing	58	260	72	740
E- Water supply; sewerage, waste management and remediation activities	1	8	1	1
F- Construction	6	59	8	394
G- Distributive trades[b]	-	-	18	602
H- Transportation and storage services	-	-	1	156
I- Accommodation and food service activities	-	-	2	2842
J- Information and communication services	35	1967	15	1126
M- Professional, scientific and technical activities	51	1340	18	2108
N- Administrative and support service activities	2	3896	3	516
P- Education	-	-	2	3
Q- Human health and social work activities	24	1146	1	2
R- Arts, entertainment and recreation	2	1299	1	25
S - Other services activities	1	21	1	59

Notes: None of the sample companies operated in B: Mining and quarrying; D: Electricity, gas, steam and air conditioning supply; K: Financial and insurance activities; L: Real estate activities; O: Public administration and defence, compulsory social security; T: Activities of households as employers; or U: Activities of extraterritorial organisations and bodies.

[a] Unlike for other support activities, the eligibility criteria for R&D vouchers do not exclude the activity category G- 45.2.0: maintenance and repair of motor vehicles.

Source: Author's own calculations.

and expanding literature on SME grants (see Dvouletý et al., 2020), but also draws on lines of literature that handle the factors and determinants of innovation, R&D and exporting activities at SMEs (Kiss et al., 2018). Descriptive statistics on the estimation variables are divided into three sections for (1) productivity, employment and export outcome variables, (2) covariates in the selection, and (3) covariates in the outcome equation, and they are presented in Table A3 in Appendix A.

Labour productivity is the total volume of output produced per unit of labour in a given fiscal year and we measure it by the ratio of value-added relative to the average number of employees in the fiscal year. The *employment* outcome is a percentage change in the average number of employees from the previous fiscal year. The *export* outcome marks export intensity and we measure it as a ratio of export revenues to total sales revenues for the given fiscal year. To handle abnormal values and reduce heteroscedasticity we employed some monotonic transformations of variables, such as a logarithm transformation on labour productivity that removes anomalous negative values, and an inverse hyperbolic sine (*asinh*) transformation that approximates the natural logarithm transformation, but allows zero-value and negative observations on the employment change variable to be retained.

To account for the endogenous selection into treatment, we consider several company demographic variables such as the maturity cohort of the company as the number of years in operation, and its size in assets and in number of employees. Garcia-Quevedo et al. (2014) find that the innovation behaviour of newly established companies is more erratic and their business strategy is more demand-pull driven than that of mature companies. Equally there is a large literature that confirms the relationship between company size, exports and innovation capacity (see Pla-Barber & Alegre, 2007 for an overview).

The *capital intensity* variable reflects the capital structure of the company and it measures tangible fixed assets per employee. Czarnitzki and Lopes-Bento (2014) claim that capital intensive companies have a higher propensity to innovate and are more prone to apply for public support for innovation and development. Lee and Noh (2009) separate the technology-push and market-pull factors as essential drivers of the R&DI incentives of companies. Capital intensity may at least partly capture the innovation capacity and technology-push factors of the company. Kiss et al. (2018) though find evidence of resource slack or excess production capacity as an important determinant of exports and internationalisation. The indicator for *smart specialisation* accounts for the companies that operate in the innovation and R&D policy priority area and that then have an advantage in the CP allocation process. The growth areas for Estonian smart specialisation are (1) information and communication technology (ICT); (2) health technologies and services; and (3) more efficient and enhanced exploitation of resources using research in material science, in green, passive house construction, and in the health enhancing food industry (Table 3).[20]

The indicator variable *previous periods support* takes the value 1 if the firm received CP support from the previous support period in 2007–2013 and 0 otherwise, and it denotes the control for endogenous selection into funding if the company received funding from the previous programme period (Table 4). The companies with a CP funding history may have an advantage in the application process, firstly because they have already had a chance to improve their innovative and development capacity over the previous funding period and secondly because they have learned from the application and implementation process for the previous project.

The analysis incorporates a regional indicator separating the two main economic centres and their surrounding regions in Estonia, these being the region of the capital city Tallinn, or North Estonia (Harjumaa county), and the region of the main university city Tartu in South Estonia. The region dummies capture the confounding effect from the regional business environment and the availability of local productive resources, an aspect that is identified in the literature as crucial given the evidence that knowledge-intensive and innovative companies tend to cluster in metropolitan areas (Pinto et al., 2015). The statistical classification of economic activities in the European Community (NACE2) controls for the sector effects in the selection process and captures some of the unobserved heterogeneity related to economic activity (Czarnitzki & Lopes-Bento, 2014). Table 5 shows the division of sample companies by treatment status and NACE2 economic activity.

The residual endogenous selection into support, or treatment that

[20] For more information on smart-specialisation priority areas by the Ministry of Economic Affairs and Communications in Estonia see https://mkm.ee/en/objectives-activities/economic-development/smart-specialisation.

Table 6
Sample companies by ownership type and treatment status.

	R&D clusters		R&D vouchers	
Foreign owned	YES	NO	YES	NO
$D_{d=1}$	19	705	6	280
$D_{d=0}$	168	9387	137	8294

Source: Compiled by the authors.

remains unobserved is controlled for by introducing the Inverse Mills Ratio in the outcome equation.[21] The covariates in the outcome equation are the age and size of the company and the performance indicators that may contribute to its labour productivity, employment and export outcomes. The company's *age* is computed using the registration date in the registry data and it is censored at 30 years to reduce excessive variation and to avoid counting the years of operation before Estonia regained its independence and reintroduced a market economy in the beginning of the 1990s. The *number of employees* as recorded in the company's registry data give its size, and another measure of size is the variable *Sales revenues*, for total revenues, measured in thousands of euros. A large body of literature has stressed that smaller and younger firms are more likely to face financial constraints (see Czarnitzki, 2006; Kaplan & Zingales, 1997; Männasoo & Meriküll, 2020; Srhoj et al., 2019) and may thus have a restrained capacity for innovation and development. The covariates *cash* and *cash equivalents* measured in thousands of euros represent the liquidity that enables companies to meet unforeseen liabilities and unleash their growth potential (García-Teruel & Martínez-Solano, 2008). *Net Income After Taxes* (NIAT) captures the market value and profitability as a sign of the expected growth and earnings potential (Gold, 2005) of the company.

Intangible assets intensity is the ratio of intangible assets over total assets, and it controls for the stock of intangible goods such as software, licences or patents that can be considered as efficiency-increasing and growth-enhancing potential. The spectrum of intangible factors is, however, broader than what the balance sheet presents and it includes factors like human capital, social capital and technological capital (Dettori et al., 2012). In this study, the social and technological capital of firms are not measured explicitly, but as proposed by Moretti (2004) the human capital effect is proxied with wage returns defined as total monthly salary expenditure per person employed.

The outcome equation also includes covariates on exports per person employed, a foreign ownership dummy, and the Herfindahl-Hirschman market concentration index (HHI). *Exports per person employed* divides the export revenue of the firm by the average number of people employed and it captures several gains from internationalisation such as knowledge spill-overs, learning from exporting, technology diffusion and economies of scale (Javorcik, 2004; Masso & Vahter, 2019; Rodil-Marzabal et al., 2016). Moreover, it is also found that large and initially more productive firms (Aw et al., 2008; Costa et al., 2017; Fabling & Sanderson, 2013) that pay higher salaries are more likely to engage in exporting, and among those firms, the subsequent productivity gains from exporting are the highest for exporters of high value-added products (Wagner, 1995, 2001). The *foreign ownership* indicator controls for differences in productivity, exporting and employment that may stem from the type of ownership (Table 6).

Costa et al. (2017) report a productivity premium attributed to foreign ownership. Finally, the HHI is calculated using the turnover of the firm over the total turnover of the NACE 2 division to control for the degree of competition the firm faces in its sector market, and this accounts for performance effects driven by the market division (see also Chaney & Ossa, 2013). Table A2 in Appendix A details the description and explains the calculations and units of all the variables used in the estimation process. The nominal monetary values are deflated using the value-added and capital deflators on the level of the NACE 2-digit industry code. The average salary variable is deflated using the Consumer Price Index (CPI) deflator.

[21] The unobserved endogenous selection may occur due to attrition that is non-random and is related to annual reporting practices including reporting quality and consistency.

4. Estimation strategy

The central aim of the policy evaluation is to estimate the causal effect of a policy intervention, or a treatment, on some observable outcomes targeted by the policy. The analytical complication is in setting up a counter scenario, a counterfactual that constitutes the hypothetical outcome the treated unit would have had if it had not received treatment, and that for the untreated unit if it had received treatment. The standard framework used to formalise the problem is the potential outcome model by Rubin (1980), who stated that with randomised treatment, the potential outcome under alternative treatment forms an adequate counterfactual. In observational studies, including quasi-experimental designs, the randomised treatment condition is not satisfied and additional measures need to be taken to meeting the ignorability (or unconfoundedness) assumption $(Y(1), Y(0)) \perp D$, which implies that the treatment assignment D is independent of the outcomes Y. A substantial and growing body of methodological research has proposed solutions for correcting selection bias conditional on observables that allow treatment to be estimated under unconfoundedness, including matching techniques, regression adjustment with inverse probability weighting (IPW), regression discontinuity design, and difference-in-difference, imputation and projection techniques, and hybrid-class methods (Abadie & Cattaneo, 2018; Bickel et al., 1993; Cattaneo, 2010; Imbens & Rubin, 2015; Imbens & Wooldridge, 2009; Rosenbaum & Rubin, 1983; Wooldridge, 2007).

Our research setting corresponds to the quasi-experimental design, which needs a control for the selection into treatment and the corresponding corrections for the counterfactual. Czarnitzki and Lopes-Bento (2014) stress that the regulatory requirements and eligibility criteria of the public support schemes are likely to introduce treatment selection biases. In consequence, our empirical analysis of the causal inference of the support treatment effect is done in two steps. The first step is to calculate the generalised propensity scores (GSP), and the second is to run the semi-parametric inverse probability weighting (IPW) estimation using the novel efficient influence function estimator (EIFE) proposed by Cattaneo (2010). In doing this, the regression adjustment and matching techniques provide a solution for meeting the assumptions on ignorability, while the semi-parametric approach lets us circumvent the rigidity in the assumptions on the functional form.

The generalised propensity scores (GSP) technique introduced by Rosenbaum et al. (1983) controls for the selection bias and estimates the probability of treatment in the Cohesion Policy programme (CP), or the likelihood of being assigned into the *treatment group* of those benefiting from support as opposed to the control group of non-beneficiaries. In doing this, GSP allows for treated and untreated companies to be matched by similarities in their observed characteristics. The propensity score is a conditional probability of being assigned into treatment given an observed set of covariates $(D = 1|X)$, where D is a binary treatment indicator and X is a vector of observed covariates that have an effect on selection into treatment. Following this approach, we form the basis for matching treated and control enterprises that share similar propensity score values, or that are *nearest neighbours* in their score values.

The average treatment effect on the treated (ATT) is defined as the difference in the potential outcomes Y_t and $Y_{t'}$ for two different episodes t and t' or, in other words, the expected causal effect of the treatment for firms in the treatment group $\tau_{ATT} = E[Y_t - Y_{t'}|D = 1]$ where just one of the outcomes is observed for each unit. The average causal effect of the

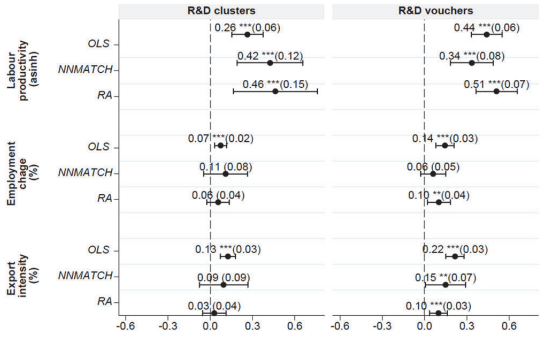

Fig. 1. Estimation results. Notes: Point estimates for the average treatment effect on treated (ATT reported surrounded by 95 % confidence intervals), standard errors in parentheses. OLS – Ordinary Least Squares; NNMATCH – one-to-one Nearest Neighbour Matching using Mahalanobis distance; RA – Regression Adjustment. ***, **, * represent statistical significance given $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Compiled by the authors.

treated company can be rewritten as $\tau_{ATT} = E[Y_{1i} - Y_{oi}|D_i = 1] = E[Y_{1i}|D_i = 1] - E[Y_{oi}|D_i = 1]$. The expression highlights the counterfactual nature of the causal effect with the first term indicating the average effect in the population of firms that received support, an observed quantity while the second term is the counterfactual of no support for the treated firms. The outcome $Y = DY_t + (1 - D)Y_{t'}$ manifests causal inference conditioned on the realisation of treatment (Holland, 1986). The outcome and the selection equation regressors are predetermined and observed in a pre-treatment period to avoid the endogenous feedback that may otherwise arise between the characteristics of the firm and the treatment effects. The empirical strategy employs a hybrid method that combines matching and regression adjustment with inverse probability weighting (IPW).

The IPW reweights the observations with estimated propensity scores and so removes confounding and generates a pseudo-population in which the treatment is independent of the measured confounders (Wooldridge, 2007). The IPW-adjusted regression analysis in his way purges the estimates of the treatment-specific predicted outcomes from the imperfect matching (Abadie & Cattaneo, 2018). The doubly robust efficient influence function (EIF) proposed by Cattaneo (2010) relies particularly on a two-step semi-parametric Generalised Method of Moments (GMM), where the first step is fully non-parametric and accounts for the potential non-smoothness in the moment conditions. The second step combines the outcomes from the moment conditions with the IPW estimates. The efficient estimator of Cattaneo (2010) and Cattaneo et al. (2013) bears a doubly robust property that allows for correction of the bias that may arise from imperfect matching or from functional misspecification of the model. The estimation, however, remains dependent on the assumptions in the selection-on-observables and common support that guarantee the ignorability condition.

For the sake of robustness, we additionally use the marginal mean

Table 7
GPS estimation results.

	R&D clusters		R&D voucher	
	GPS estimation with interaction terms	GPS estimation without interaction terms	GPS estimation with interaction terms	GPS estimation without interaction terms
North	2.842***	3.572***	1.062	1.195
	(0.92)	(0.98)	(0.25)	(0.25)
	[1.507 5.357]	[2.083 6.125]	[0.668 1.687]	[0.794 1.800]
South	2.667***	3.414***	1.555	1.528
	(0.99)	(1.07)	(0.46)	(0.40)
	[1.285 5.538]	[1.845 6.316]	[0.869 2.784]	[0.912 2.560]
Programme 2007–2013 support	3.860***	6.654***	3.616***	4.497***
	(1.80)	(1.23)	(1.31)	(0.96)
	[1.544 9.649]	[4.631 9.561]	[1.776 7.365]	[2.957 6.838]
North ## Programme 2007–2013 support	1.881		1.641	
	(0.97)		(0.77)	
	[0.684 5.174]		[0.658 4.095]	
South ## Programme 2007–2013 support	1.999		0.931	
	(1.27)		(0.57)	
	[0.573 6.969]		[0.282 3.069]	
Age cohort	1.422*	1.413*	1.485**	1.482**
	(0.27)	(0.27)	(0.28)	(0.28)
	[0.975 2.072]	[0.970 2.059]	[1.027 2.146]	[1.025 2.142]
Size class	5.664***	5.684***	2.714***	2.707***
	(1.13)	(1.14)	(0.63)	(0.63)
	[3.825 8.387]	[3.838 8.419]	[1.720 4.281]	[1.715 4.271]
Capital intensity	1.002***	1.002***	1.003***	1.003***
	(0.00)	(0.00)	(0.00)	(0.00)
	[1.001 1.003]	[1.001 1.003]	[1.001 1.006]	[1.001 1.006]
Smart specialization	13.147***	13.217***	1.171	1.192
	(3.47)	(3.47)	(0.27)	(0.27)
	[7.842 22.039]	[7.901 22.111]	[0.747 1.836]	[0.761 1.866]
N	10,279	10,279	8717	8717
aic	1133.741	1131.388	1196.863	1194.444
bic	1242.309	1225.48	1302.958	1286.393

Notes: Semiparametric maximum likelihood estimates. Odds ratios reported, standard errors in parentheses, 95 % confidence intervals in square brackets. ***, **, * represent statistical significance $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively. Regressions with second-order polynomial interaction terms include interactions between the regional indicator variables and the 2007–2013 support programme.
Source: Author's own calculations.

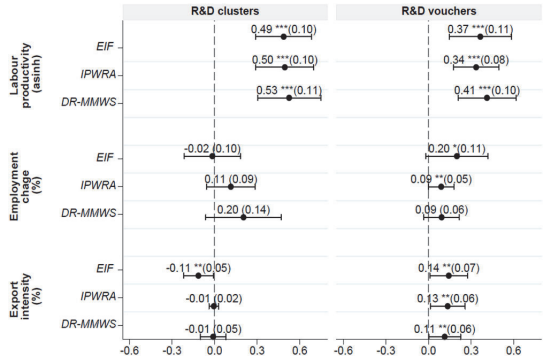

Fig. 2. Estimation results. Notes: Point estimates for the average treatment effects on treated (ATT reported surrounded by 95 % confidence intervals), standard errors in parentheses. EIF – Efficient Influence function; IPWRA – Inverse Probability-Weighted Regression Adjustment; DR-MMWS – Doubly-Robust Marginal Mean Weighting through Stratification. ***, **, * represent statistical significance given $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Compiled by the authors.

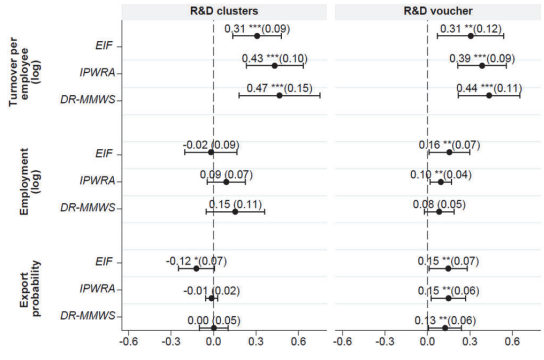

Fig. 3. Robustness check using an alternative specification of the outcome. Notes: Point estimates for the average treatment effects on treated (ATT reported surrounded by 95 % confidence intervals), standard errors in parentheses. EIF – Efficient Influence function; IPWRA – Inverse Probability-Weighted Regression Adjustment; DR-MMWS – Doubly-Robust Marginal Mean Weighting through Stratification. ***, **, * represent statistical significance given $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Compiled by the authors.

Table 8
Selection effect on inverse probability weighted outcome values for the treated and control groups at pre-treatment and post-treatment period, unconditioned on the outcome equation covariates.

	R&D clusters		R&D voucher	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Inverse probabilty weights derived from GPS estimations with interaction terms				
Labour productivity (asinh)	1.155(0.18) [0.850; 1.571]	1.637*** (0.22) [1.255; 2.136]	1.211(0.18) [0.900; 1.629]	1.642*** (0.28) [1.170; 2.306]
Employment change (%)	1.263* (0.17) [0.972; 1.639]	0.984(0.09) [0.832; 1.177]	1.171(0.23) [0.792; 1.731]	1.303** (0.17) [1.009; 1.682]
Export intensity (%)	1.003(0.01) [0.987; 1.018]	1.006(0.01) [0.984; 1.028]	1.033** (0.01) [1.007; 1.060]	1.117* (0.07) [0.987; 1.265]
Inverse probabilty weights derived from GPS estimations without interaction terms				
Labour productivity (asinh)	1.116(0.18) [0.817; 1.525]	1.606*** (0.22) [1.233; 2.091]	1.211(0.18) [0.900; 1.629]	1.674*** (0.28) [1.203; 2.329]
Employment change (%)	1.309* (0.19) [0.992; 1.727]	0.972(0.09) [0.806; 1.173]	1.160(0.22) [0.803; 1.677]	1.288** (0.16) [1.011; 1.641]
Export intensity (%)	1.002(0.01) [0.986; 1.019]	1.004(0.01) [0.984; 1.026]	1.035** (0.01) [1.007; 1.063]	1.115* (0.07) [0.991; 1.254]
N	10,279	10,279	8717	8717

Notes: Inverse probability weights, compiled as generalized propensity scores (GPS), can be found in Table 7. Inverse probability-weighted outcomes regressed on the binary treatment selection. Table reports binary selection indicator coefficients, standard errors in parentheses and 95 % confidence intervals in square brackets. ***, **, * represent statistical significance $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Author's own calculations.

weighting through stratification (MMWS) adjustment proposed by Linden (2017), which is a weighting strategy that provides correction of the propensity score-based weighting for cases where the misspecification of the selection equation distorts the propensity score estimates. MMWS uses the probability of assignment to the treatment group and calculates the marginal mean weights of that probability by strata. Since membership of a stratum does not change and does not depend on the functional specification of the propensity score estimation, the MMWS provides a robust non-parametric alternative to the more standard IPW.

5. Results

The Fig. 1 presents the effects of R&D clusters and R&D vouchers support on firm's labour productivity, employment and export intensity using conventional outcome-based least squares, one-to-one matching on covariates, and regression adjustment methods. The results indicate that R&D clusters support has a statistically significant effect on firm's labour productivity gains, but R&D voucher support also contributes to the firm's employment and export intensities. While the latter methods solve the outcome relevant missing variable problem, these methods do not correct for the selection bias arising from the firm's self-selecting into the treatment and agency selection of stronger candidates to final beneficiaries (Dimos & Pugh, 2016).

The generalised propensity score (GPS) estimates presented in Table 7 confirm a non-random selection into treatment, showing that larger and more established companies operating in knowledge-intensive sectors are more likely to benefit from the R&DI support. This evidence is in line with the findings of Garcia-Quevedo et al. (2014) and Pinto et al. (2015).[22] The estimated average treatment effects on the treated (ATT), shown in Fig. 2, along with the illustrated changes in the outcome variables of main interest among the treatment and control groups (see Fig. 2 and Appendix Fig. A2), show that the CP support varied considerably in its effect between the two R&DI support activities, with a dominating positive effect on the labour productivity of

[22] Dimos and Pugh (2016) refer to public choice theory and the opportunistic behaviour of public agencies in cherry-picking the beneficiaries that have highest probability of succeeding in fulfilling the policy aims.

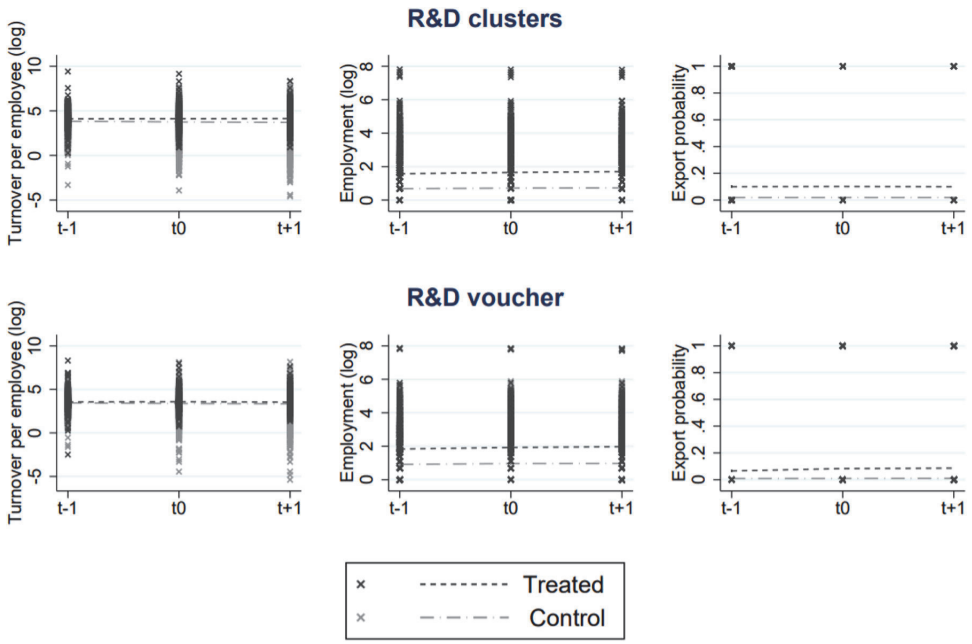

Fig. 4. Change of the alternative specification outcome variables in the treatment and control groups.
Source: Compiled by the authors.

companies, a moderate positive effect on employment, and an ambiguous effect on export intensity. The short-term labour productivity gains for the beneficiary companies were on average 30–35 % for the R&D voucher activity and 48–51 % for the R&D clusters activity.

To assess whether the inverse probability weighting conducted in the first step of the estimation (see GPS results in Table 7) handles the non-random treatment assignment well, we carry out simple regressions (unconditional on outcome regression covariates) of inversely-weighted outcome variables on the treatment dummy and test for the significance of the treatment slope coefficient for the treatment and control groups at pre-treatment and post-treatment periods The inverse probability weighting in the first estimation step aims to generate well-balanced populations for the treatment and counterfactual groups that are homogeneous in their pre-treatment outcomes and show divergence in outcome values only post-treatment. Table 8 reports the slopes, standard errors, and 95 % confidence intervals of the treatment slope in the outcome variable regressions on the inversely-weighted sample observations. The results are in alignment with the baseline results (Figs. 1–4, Table A4) and show that the inverse-weighting procedure has led to an expected outcome in that treatment assignment has mostly no effect on outcome values before treatment, but has a significant effect only post-treatment. This robustness check helps to demonstrate that the covariates in the outcome equation are not biasing the main results and this supports the validity of the critical assumption that outcome equation covariates must not be endogenous to the treatment assignment.

A positive change in employment of 9–20 % as the average treatment effect could be observed only for companies that were supported with R&D vouchers, while only marginally significant evidence was found for those that got funding from the R&D clusters activity. The effects on export intensity outcomes were considerably different for the two support activities and across estimation procedures, and they are partly measured with low precision. Interestingly, the export intensity was lower for the companies that benefitted from the R&D clusters activity than it was for the control group, whereas the export intensity was higher (at between 11% and 14%) for companies that received R&D voucher activity support according to the baseline estimation.

Our estimate of the treatment effect on employment for the R&D voucher activity resembles the average treatment estimates of Benkovskis et al. (2018), who studied the performance of Latvian companies with and without the European Regional Development Fund (ERDF) support schemes. The study reports a 13–14 % increase in employment at the Latvian companies during a year after the support was received, and of around 17 % on average after treatment had been received for two years across the ERDF support schemes. Unlike those of Benkovskis et al. (2018), our results show a significant positive short-term effect on labour productivity in Estonia that is substantial in magnitude, while the Latvian research reported a labour productivity increase of around 12 % over a period of three years, but no short-term impact. Reflecting our ambiguous results, Benkovskis et al. (2018) find only a negligible effect from ERDF funding on the export intensity of Latvian companies. Our results are also broadly in line with the findings of Bachtrögler et al. (2020) for labour productivity and employment changes at the Central and Eastern European companies that benefitted from EU funding schemes.

The robustness checks carry out estimations with alternative specifications. To do this, we define productivity by dividing turnover by the

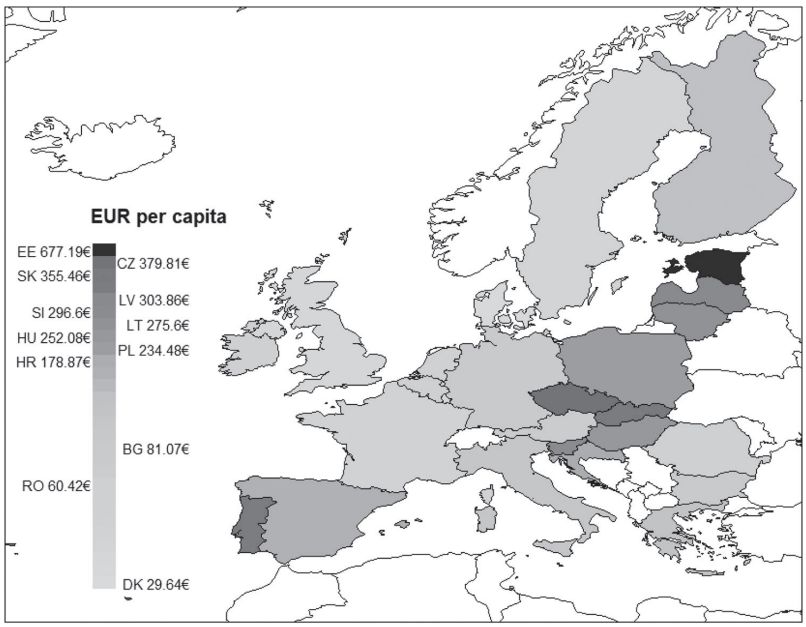

Fig. A1. Cohesion Policy Programme 2014–2020 R&DI targeted total funding per capita.
Source: Authors' calculations based on the European Structural and Investment Funds (ESIF) (https://cohesiondata.ec.europa.eu/2014-2020/ESIF-2014-2020-FINANCES-PLANNED-DETAILS/e4v6-qrrq/data) 2014–2020 statistics and Eurostat population statistics (series: demo_gind).

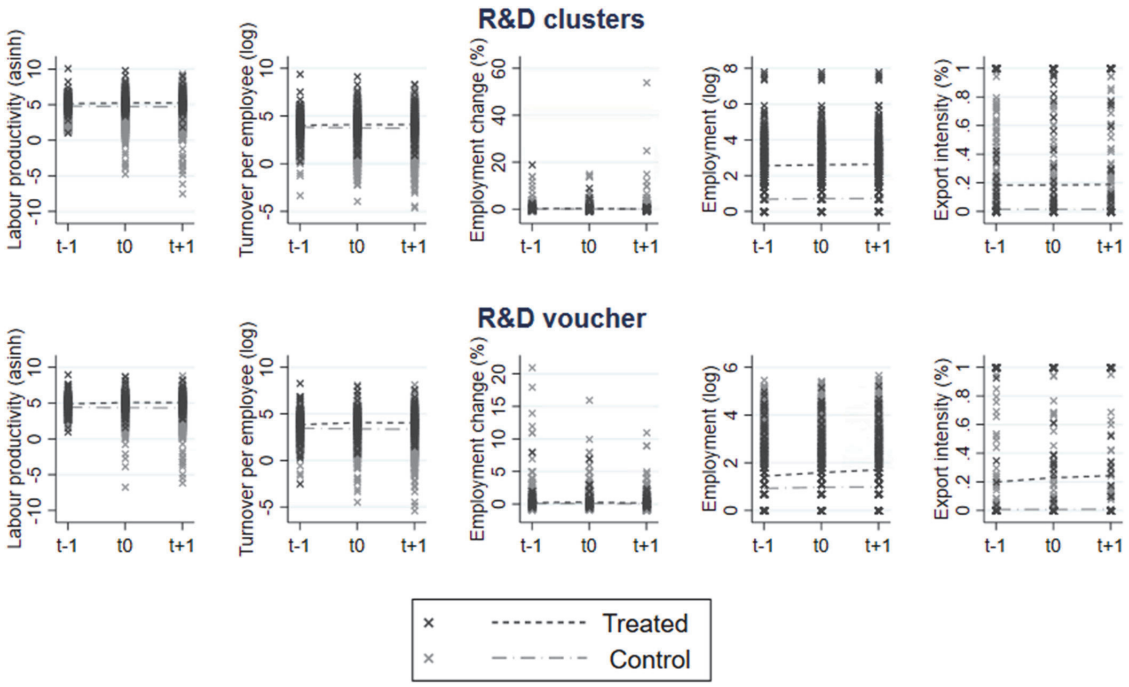

Fig. A2. Distributions and means of the unweighted and unconditional outcome variables for the treatment and control groups at pre-treatment, treatment and post-treatment period. *Notes:* Individual company observations in unweighted and unconditioned outcome variables for treated and non-treated or control companies at pre-treatment (t-1), treatment (t0) and post-treatment (t + 1) periods. Dashed lines represent the mean values for the treated and control groups.
Source: Compiled by the authors.

number of employees following Czarnitzki et al. (2011) and Czarnitzki and Lopes-Bento (2014), employment by taking the log transformation of the average number of employees at companies following Benkovskis et al. (2018), and exports as the exporting status. The alternative specification estimates (Fig. 3 and Appendix Fig. A2) complement the baseline findings, indicating that CP innovation support schemes have a persistent pronounced effect on productivity, while the estimates for exports and employment are almost interchangeable given the particular support scheme.

A notable difference between the baseline and robustness estimates arises from the magnitude of the productivity estimates, which show a slightly larger average treatment effect for the R&D voucher support than for the R&D clusters support. This can be explained by the central objectives of the two support schemes. R&D clusters support promotes inter-cluster research cooperation, focusing on more disruptive innovative outcomes stemming from knowledge-sharing between sectors and research disciplines. The R&D voucher, on the other hand, targets improvements in competitiveness and an increase in value added not only from radical innovation, but also from incremental innovation. The R&D voucher effect on the productivity outcome as measured in turnover per labour unit was higher than it was on the productivity outcome measured in value added per labour unit. Masso and Vahter (2007) used the Community Innovation Survey (CIS3 and CIS4) and Estonian company registry data from 1995 to 2005, and showed that while the process innovation had a significant effect on productivity, there was no such effect for product innovation. This evidence is in line with our findings, which confirm that productivity outcomes in turnover related to efficiency and processes have a more important role than the outcomes in value added that are related to changes in technology.

Our findings that public support targeted at R&DI has a strong impact on labour productivity are broadly in line with those of Fattorini et al. (2020) and Rodríguez-Pose and Fratesi (2004), who similarly show that public grants have a positive impact on total factor productivity. The relatively modest results for employment may be explained by the dual role of innovation and R&D in employment, as they may displace jobs through automation and increased efficiency, but also generate new demand and new jobs (Acemoglu & Restrepo, 2018). Another explanation for why the short-term employment effects are modest may be that the new jobs in R&DI activities emerge with a considerable time-lag, and this may be particularly relevant for activities related to R&D clusters and collaborations, where the positive effect on economic outcomes stems from spill-overs. In a similar manner the export effect from R&DI manifests with a time-lag, whereas the more radical innovations need a longer time for incubation and for procedures to protect intellectual property before they can be launched on foreign markets.

6. Lessons learned

The evaluation of the impact of R&DI support activities funded by Cohesion Policy on the performance of SMEs in Estonia casts light on the effectiveness of the European public fund allocations in generating structural growth effects in the enterprise sector of a small member state that has the highest per capita support intensity in the European Union. The high support intensity may imply considerable spillover effects in the enterprise sector and in the economy at large. The impact analysis is conducted on an extensive dataset that contains a rich set of variables from the population data of the companies' registry, however, it does not allow for controls on ownership linkages, and supply chain linkages. The absence of information for identifying the spillover effects and mechanisms of support effect transmission does not enable for the evaluation of the indirect impact affecting internal and external business partners of the beneficiaries. Further work that also incorporates the spillover effects would be highly regarded. Moreover, the Cohesion Policy support waves do not have only contemporaneous or short-term effects, but also accumulative effects over time. In view of this, the current analysis controls for the effect of the support during the previous financing period and in doing so separates the effects of the current and past wave. It would, however, be valuable to study not only the effect of a particular support measure in a given financial period, but also the accumulative effect of allocated public support over time across subsequent financing periods. This task was not in the scope of the current analysis, however, it would be valuable to address the question in the future research, but to do this, longer series of well-structured support data and estimation frameworks that accommodate the dynamics of time-varying environmental factors are needed.

A critical assumption for a valid impact assessment is the conditional independence between the treatment and the outcome. For that purpose, the quantitative impact estimation uses the complementarity of matching and inverse weighting techniques. Selection and combination of quantitative estimation tools, however, does not substitute for a well-planned study design. The current analysis employed not only contemporary estimation methods, but also exploited detailed field information in setting up the treatment and control groups. The gathering of field information involved consultations with experts from the agencies administrating support who provided insights related to support eligibility criteria, selection and allocation procedures which helped to exclude companies, that would otherwise not conform with the evaluation sample and violate the conditional independence criteria.

The unique and detailed population dataset was a valuable source for the current quantitative evaluation and inference of the support effect, but it does not allow for a deeper understanding on the underlying mechanisms that translate the allocated R&DI funds into productivity or productive capacity outcomes. The latter requires qualitative background information on companies' managerial and human resources, technology adoption or other measures of absorptive and innovative capacity. Stame (1999) underlines the importance of qualitative data in the evaluation of aid programs and Pelucha et al. (2019) similarly stress the value of mixed-methods that employ the virtues of both, the administrative and qualitative data, thereby not only enabling to achieve a better evaluation of the measured extent of the support effect, but also gain insight on how the support mechanisms operate. Hence, the next challenge in conducting policy evaluations is to merge the demography and performance registry data with qualitative information on the companies' strategies and capacities in using the allocated resources. The mixed use of quantitative and qualitative information would allow for a better interpretation of the results and for more informative policy implications but it may elicit trade-offs between sample-size sensitive measurement accuracy and dimensionality demanding interpretability.

7. Conclusion

The current study evaluated how R&DI support activities funded by CP affect employment, productivity and export intensity of SMEs in Estonia. Estonia is the highest per capita net recipient of funding from the CF programme period 2014–2020, and European funds comprise a substantial share of the country's public R&DI investments. The country's ultimate policy is to target productivity and employment growth

spurred by R&DI along with stronger export competitiveness. The extant empirical evidence on how effective public support is in achieving these policy aims is inconclusive and for the new member states with a post-communist transition history this evidence is only recent and is still limited.

Our analysis employs a semi-parametric efficient estimation by Cattaneo (2010) and Cattaneo et al. (2013), which in its first step employs moment conditions to estimate the generalised propensity scores and in the second step plugs those scores into an efficient influence function, which is a weighting procedure that accounts for the non-random selection into support, or treatment. Like most of evidence in the literature evaluated, with a few exceptions like Gustafsson et al. (2020), our analysis confirms the presence of a non-random selection into treatment, which is in line with public choice theory, as it is the better-endowed companies that have a higher probability of succeeding in achieving the performance targets set by the policy. Controlling for this selection, we find like most of the previous literature that the impacts that the two R&DI support activities under investigation have on the outcomes of productivity, employment and export intensity are quite different in magnitude. Overall, however, both the R&D voucher activity and the R&D and technology clusters activity show desirable policy outcomes with a positive effect on the labour productivity of companies and a moderate positive effect on employment, with only the effect on export intensity remaining ambiguous. These results are even more encouraging given that the effects are only short term and are measured within 2–3 years of the start of treatment. The labour productivity gains ranged from 34 % to 42 % for the R&D voucher activity up to 49–53 % for the R&D and technology clusters activity. An increase in employment of 9–20 % was found for the R&D vouchers activity, but the effect was only marginally significant for the clusters activity. The evidence for the export intensity outcome was conflicting, as the R&D voucher activity had a moderate positive effect on export intensity, but the clusters activity had a negative one. The study most similar in context to ours is Benkovskis et al. (2018), which finds broadly corroborating results in Latvia, Estonia's southern neighbour, and which puts forward the time-lag argument, which may explain why there are no conclusive short-term results for the export outcomes. Unlike those of Benkovskis et al. (2018) however, our results for the improvement in productivity are stronger and are already apparent within a short treatment period. The evidence for a positive effect on employment, which has been one of the most robust results in the literature, finds only modest confirmation in our study.

CRediT authorship contribution statement

Simona Ferraro: Literature Review, Methodology, Writing – review & editing, Manuscript preparation of Sections 2 and 4 with input from all authors. **Kadri Männasoo:** Literature Review, Methodology, Manuscript structure, Writing of Sections 1, 2.1 and 5 and study "Highlights" with input from all authors, Answers to the Reviewers. **Helery Tasane:** Data Collection and Management, Visualization and Output Tables, Manuscript preparation of Sections 3 and 5 with input from all authors. All authors discussed the results, contributed to Section 7 and participated in reviewing and editing the manuscript.

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Appendix A

See Figs. A1 and A2, Tables A1–A4.

Table A1
Economic indicators.

	2013	2014	2015	2016	2017	2018	2019
Real GDP growth. %	1.3	2.8	2.3	3.1	5.2	4.4	4.9
Consumer Price Index. %	2.8	-0.1	-0.5	0.2	3.4	3.4	2.3
Unemployment rate[b], %	8.6	7.3	6.2	6.8	5.8	5.4	4.5

[a] Unemployment: Unemployed/labour force %; based on the Labour Force Survey, up to 1997 people aged 15–69, from 1997 people aged 15–74. https://statistika.eestipank.ee/#/en/p/MAJANDUSKOOND/r/2053/1902.
Source: Bank of Estonia, Key Economic Indicators.

Table A2
List of variables.

Variable	Description	Unit of measure	Transformed in regression model
Outcome, observed at period t + 1			
Labour productivity	Value added divided by the average number of employees at the end of financial year	th EUR per person employed, deflated with ppiv	Yes, inverse hyperbolic sine transformation
Employment change	Yearly percentage change in average employment	%	No
Export intensity	Export revenue divided by total revenue	%	No
Treatment, observed at period t			
Treatment variable	Distinguished treated firms (1) from the counterfactual (0).	Binary (1/0)	No
Matching equation, observed at period t-1			
Age cohort	Distinguishes young firms (1) from mature (0) firms.	Binary (1/0)	No
Size class	Distinguishes firms with 10 and more employees (1) from Micro firms (0).	Binary (1/0)	No
North	Distinguishes firms who are located in Harju county (1) which lies in the Northern region of Estonia from the counterfactual (0).	Binary (1/0)	No
South	Distinguishes firms who are located in Tartu county (1) which lies in the Southern region of Estonia from the counterfactual (0).	Binary (1/0)	No
Capital intensity	Balance sheet value of tangible assets at the end of fiscal year divided by the average number of employees.	th EUR per person employed, deflated with ppik	No
Previous period supports	Distinguishes firms who have received Cohesion Policy ERF supports from previous support period (1) from counterfactual (0).	Binary (1/0)	No
Smart Specialisation	Distinguished firms' who have implemented smart specialisation in daily operations (1) from counterfactual (0)	Binary (1/0)	No
NACE 2 Division	Set of NACE 2 division indicator variables distinguishing firms who belong to the given NACE 2 division (1) from counterfactual (0)	Binary (1/0)	No
Outcome equation, observed at period t-1			
Age	Age calculated from the firms' registration date	Years, bounded with 50 years	Yes, square transformations for non-linearities.
Number of employees	Average number of employees by the end of financial year.	Continuous	Yes, log and log square transformations for non-linearities
Turnover	Total turnover at the end of financial year.	th EUR, deflated with ppiv	Yes, log transformation
Average monthly salary	Total annual salary expense divided by the number of employees and 12 months.	th EUR in month, deflated with cpi	No
NIAT	Annual profit/loss	th EUR, deflated with ppiv	Yes, inverse hyperbolic sine transformation
Cash and cash equivalents	Cash and cash equivalents at the end of the financial year	th EUR, deflated with the ppik	Yes, log transformation
Intangible assets intensity	Balance sheet value of intangible assets at the end of the financial year	%	No
Export revenue per person employed	Export revenue divided by total revenue	th EUR per person employed, deflated with ppiv	No
Foreign ownership	Distinguishes foreign-owned firms (1) and domestic-owned firms (0).	Binary (1/0)	No
Local supports	YTD value of business grants received from local funds.	th EUR, deflated with ppiv	No
Multiple sources of support	Distinguishes firms who have received Cohesion Policy ERDF support from other measure activities as well	Binary (1/0)	No
More than one	Distinguishes firm who receive recurrent support from the same measure activity	Binary (1/0)	No
HHI (*Herfindahl-Hirschman*)	$HHI = \sum_{i=1}^{N} S_i^2$ Where i denotes individual firm belonging to given NACE 2 division and s denotes firms sales revenue from total given NACE 2 division sales revenue.	< 0.01 very low concentration < 0.15 low concentration $0.15 \leq$ HHI < 0.25 moderate concentration ≥ 0.25 high concentration	No
Inverse Mills Ratio	Probability of being missing from the sample given the firm's size characteristics	Continuous probability	No

Table A3
Descriptive statistics.

		Treated			Control				
	Variable	No obs	Mean	SD	No obs	Mean	SD	Mann-Whitney	
Outcome	Labour productivity	313	188.462	642.468	17,032	69.157	84.97	-11.768	***
	Employment change	329	0.224	0.855	17,170	0.096	0.505	-5.069	***
	Export intensity	329	0.204	0.388	17,170	0.011	0.103	-32.829	***
Selection equation covariates	Age cohort	329	0.468	0.5	17,170	0.482	0.5	0.498	
	Size class	329	0.45	0.498	17,170	0.122	0.328	-17.568	***
	North	329	0.574	0.495	17,170	0.612	0.487	1.39	
	South	329	0.201	0.401	17,170	0.115	0.319	-4.799	***
	Capital intensity	325	24.371	81.45	16,395	25.798	100.033	-3.883	***
	Programme 2007–2013 support	329	0.404	0.491	17,170	0.06	0.238	-24.747	***
	Smart specialisation	329	0.486	0.501	17,170	0.081	0.273	-25.566	***
Outcome equation Covariates	Age	329	10.693	6.943	17,170	9.906	5.92	-1.321	
	Number of employees	329	47.699	221.445	17,170	5.079	11.238	-15.759	***
	Turnover	329	7141.42	68,375.63	17,170	233.707	621.364	-17.579	***
	Average monthly salary	326	1.101	1.82	17,117	0.526	0.505	-14.875	***
	Net income after taxes (NIAT)	329	337.602	2957.09	17,138	20.353	85.687	-8.918	***
	Cash	326	295.735	956.833	16,232	46.715	131.943	-9.472	***
	Intangible assets intensity	329	0.055	0.156	17,170	0.005	0.04	-25.547	***
	Export per person employed	329	686.742	7482.48	17,170	11.261	264.354	-32.912	***
	Foreign owned	329	0.076	0.265	17,170	0.055	0.228	-1.656	*
	Local supports	329	1.435	16.871	17,170	0.067	0.972	-7.919	***
	Multiple sources of support	329	1	0	17,170	0	0	-132.28	***
	More than one support	329	0.043	0.202	17,170	0	0	-27.04	***
	Herfindahl-Hirschman Index (HHI)	329	0.037	0.078	17,170	0.028	0.071	-2.283	**

Notes: Mann-Whitney test statistics on comparison of control and treatment group. ***, **, * represent $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Author's own calculations.

Table A4
Regression results.

	Labour productivity (asinh)	Employment change (%)	Export intensity (%)	Turnover per employee (log)	Employment (log)	Export probability
Activity 4.2.4: R&D clusters						
OLS	0.264***	0.074***	0.125***	0.228***	0.085***	0.158***
	(0.06)	(0.02)	(0.03)	(0.07)	(0.02)	(0.03)
	[0.152 0.375]	[0.031 0.117]	[0.073 0.178]	[0.100 0.356]	[0.043 0.128]	[0.100 0.217]
NNMATCH	0.425***	0.109	0.094	0.446**	0.445***	0.102
	(0.12)	(0.08)	(0.09)	(0.18)	(0.11)	(0.09)
	[0.192 0.658]	[− 0.047 0.266]	[− 0.078 0.267]	[0.084 0.808]	[0.221 0.669]	[− 0.073 0.278]
RA	0.462***	0.056	0.029	0.403**	0.054	0.048
	(0.15)	(0.04)	(0.04)	(0.17)	(0.04)	(0.05)
	[0.165 0.760]	[− 0.023 0.136]	[− 0.054 0.112]	[0.068 0.737]	[− 0.018 0.126]	[− 0.043 0.139]
EIF	0.487***	-0.016	-0.114**	0.308***	-0.018	-0.121*
	(0.10)	(0.10)	(0.05)	(0.09)	(0.09)	(0.07)
	[0.291 0.683]	[− 0.215 0.183]	[− 0.219 − 0.010]	[0.137 0.479]	[− 0.203 0.168]	[− 0.249 0.007]
IPWRA	0.495***	0.114	-0.006	0.432***	0.091	-0.014
	(0.10)	(0.09)	(0.02)	(0.10)	(0.07)	(0.02)
	[0.290 0.700]	[− 0.056 0.285]	[− 0.039 0.028]	[0.231 0.634]	[− 0.043 0.225]	[− 0.057 0.029]
DR-MMWS	0.525***	0.204	-0.01	0.466***	0.154	0.003
	(0.11)	(0.14)	(0.05)	(0.15)	(0.11)	(0.05)
	[0.303 0.748]	[− 0.062 0.470]	[− 0.100 0.080]	[0.182 0.751]	[− 0.052 0.360]	[− 0.099 0.105]
N	10279	10279	10279	10279	10279	10279
Activity 4.4.2: R&D clusters						
OLS	0.441***	0.145***	0.217***	0.453***	0.133***	0.248***
	(0.06)	(0.03)	(0.03)	(0.06)	(0.02)	(0.04)
	[0.331 0.551]	[0.079 0.210]	[0.152 0.281]	[0.336 0.571]	[0.086 0.180]	[0.178 0.317]
NNMATCH	0.336***	0.061	0.149**	0.394***	0.124	0.161**
	(0.08)	(0.05)	(0.07)	(0.10)	(0.11)	(0.07)
	[0.185 0.486]	[− 0.028 0.150]	[0.008 0.291]	[0.189 0.598]	[− 0.090 0.338]	[0.019 0.303]
RA	0.510***	0.101**	0.099***	0.508***	0.087***	0.104***
	(0.07)	(0.04)	(0.03)	(0.08)	(0.03)	(0.03)
	[0.364 0.657]	[0.020 0.183]	[0.035 0.163]	[0.360 0.656]	[0.022 0.151]	[0.037 0.171]
EIF	0.365***	0.2*	0.143**	0.306**	0.155**	0.147**
	(0.11)	(0.11)	(0.07)	(0.12)	(0.07)	(0.07)
	[0.146 0.584]	[− 0.020 0.420]	[0.009 0.277]	[0.072 0.541]	[0.012 0.299]	[0.013 0.282]
IPWRA	0.336***	0.089**	0.135**	0.387***	0.095**	0.149**
	(0.08)	(0.05)	(0.06)	(0.09)	(0.04)	(0.06)
	[0.175 0.496]	[0.000 0.178]	[0.012 0.257]	[0.216 0.558]	[0.020 0.171]	[0.028 0.271]
DR-MMWS	4.753***	0.145**	0.123**	3.792***	1.082***	0.136**
	(0.10)	(0.06)	(0.06)	(0.11)	(0.06)	(0.06)
	[4.549 4.957]	[0.021 0.269]	[0.010 0.235]	[3.572 4.011]	[0.974 1.190]	[0.020 0.252]
N	8717	8717	8717	8717	8717	8717

Notes: Point estimates reported, standard errors in parentheses, 95 % confidence intervals in square brackets. ***, **, * represent statistical significance $p < 0.01$, $p < 0.05$, and $p < 0.1$ respectively.
Source: Author's own calculations.

Appendix B. Literature

Studies	Observations	Type of data	Sample period	Estimation method	Type of R&D outcome	Main results
Aerts and Schmidt (2008)	Firm-level data. 4566 firms from Flanders and Germany	Pooled	1998–2004	Propensity Score Matching, OLS, conditional DID and Instrumental Variable (IV)	Private R&D investment	Positive effect of public R&D subsidies on firms that benefit from them.
Bachtrögler et al. (2020)	Seven European countries	Panel	2007–2013	Difference-in-differences (DID)	Firm growth: labour productivity and employment changes	Cohesion Policy support promotes firm growth in size (value added and employment) more than in productivity.
Bachtrögler and Hammer (2018)	25 EU member	Panel	2007–2013	Propensity score matching techniques and Difference-in-differences (DID)	Operating revenue per employees (growth), total factor productivity, number of employees	Firms that receive financial assistance hire more workers and increase their capital stock more. Little evidence of additional positive total factor productivity effects for the beneficiaries.
Becker et al. (2010)	NUTS-2 and NUTS-3 regional level	Panel	1989–2006	Regression discontinuity design (RDD)	GDP growth per capita, employment growth.	Positive per capita GDP growth on Objective 1 countries. No employment growth effects.
Benkovskis et al. (2018)	Firm-level data with 61,159 firms in 2006 and 113,155 in 2015.	Panel	2006–2015	Matching technique	Productivity, employment	Positive immediate effects of ERDF on firms' employment, turnover and capital stock. No findings that ERDF support has any larger effect on productivity than private funding does. ERDF beneficiaries had a larger increase in employment than private fund recipients. Productivity gains larger for ERDF participants with initially lower productivity and capital intensity, but that had higher leverage and more employees.
Bondonio and Greenbaum (2014)	Firm-level data from Northern and Central Italian regions with 47,594 firms.	Panel	2000–2003	Multiple categorical treatments of the three-step conditional difference-in-difference (CDD) model	Employment	ERDF fund allocations had a positive effect mainly on employment growth and this effect had no significant difference between the ERDF co-funded and national/regional programmes.
Colombo et al. (2011)	247 Italian-owner-managed new technology-based firms	Panel	1994–2003	Generalised method of moments (GMM)	Growth of firms' total factor productivity (TFP)	Only selective R&D subsidies, allocated on a competitive basis, increased total factor productivity of beneficiary high-tech start-ups whereas the effect of nonselective or automatic subsidies was absent.
Criscuolo et al (2019)	Firms in United Kingdom	Panel	1997–2004	Instrumental Variable (IV) strategy, Regression Discontinuity Design (RDD)	Employment, productivity	Positive employment effect may have a trade-off with productivity, since public support may lead to less productive workers being hired.
Czarnitzki and Lopes-Bento (2014)	German firms	Panel	1992–2006	Matching method	Innovation by patenting, products and patent citations.	EU grants and national grants lead to higher innovation by patents.
Czarnitzki and Lopes Bento (2013)	4761 Flemish firms	Pooled	2002–2008	Propensity score marching, Instrumental Variable	Internal R&D investment, R&D employment	Positive effects of public grants on R&D investment.
Czarnitzki et al. (2011)	12,887 firms beneficiaries of ERDF for France, Czechia and Germany	Panel	1999–2007	Difference-in-differences (DID)	Innovation measured by patents.	Cohesion Policy support did not have an effect on firms' innovative activities.
Čadil et al. (2019)	673 SMEs in Czechia	Panel	2007–2013	Propensity Score Matching, Neighbour Estimator, Difference-in-differences (DID)	Value-added and value-added per labour cost, employment and new technology.	Cohesion Policy (CP) support had no statistically significant impact on value added and value added per labour cost. A positive impact is on creation of jobs.
Dall'Erba and Le Gallo (2008)	145 European regions (NUTS-2)	Panel	1989–1999	Spatial econometric methods	Logarithms of the per capita GDP	Insignificant SF effect on regional GDP growth.
Esposti and Bussoletti (2008)	206 EU-15 regions (Objective 1)	Panel	1989–2000	Generalised method of moments (GMM)	Region's per capita (or per unit of labour) income growth rate	A positive impact of Structural Funds on Objective 1 regions is confirmed over the whole EU space.
Falk and Sinabell (2008)	1084 European regions (EU15)	Panel	1995–2004	Blinder-Oaxaca, OLS, median regression estimates	Regional growth of GDP per capita	Regions that received EU structural funds have a significantly higher growth rate of GDP per capita by 0.2 % point per year.
Fattorini et al. (2020)	273,500 European manufacturing firms from EU-28, NUTS-2	Panel	2007–2015	Semi-parametric econometric technique	Firm-level TFP	Positive impact of ERDF on R&D and firms' productivity. Highest impact for support schemes that foster

(*continued on next page*)

(*continued*)

Studies	Observations	Type of data	Sample period	Estimation method	Type of R&D outcome	Main results
				proposed by Ackerberg et al. (2015)		human capital and R&D and that target a more productive segment of enterprises.
Foreman-Peck (2013)	16,446 establishments in the UK	Cross-section	2002–2004	Propensity score matching	Innovation output	Public support has been both effective and efficient in boosting companies' innovation.
Freel et al. (2019)	Firm-level data, 6000–20,000 German firms	Panel	2001–2014	Matching method	Product, process innovation and exporting	Positive effects of public grants on R&DI for German SMEs.
Gustafsson et al. (2020)	Firm-level data with 2147 Swedish firms	Panel	1997–2013	Logistic, probit regression and count data models	Productivity	Negative relation between the grant a firm receives and firm productivity.
Görg et al. (2008)	Irish manufacturing plants	Panel	1993–1998	Difference-in-differences (DID)	Export, employment, wages	Positive effects of export grants on the introduction of new or existing products to foreign markets with additionality effects on value added, but not on employment.
Hartšenko and Sauga (2012)	Estonian firms	Panel	2004–2010	Difference-in-differences (DID)	Sales, labour productivity	Positive effects on sales and labour productivity.
Koski and Pajarinen (2013)	403,058 Finnish firms	Cross-section	2003–2008	Difference-in-differences (DID) and Instrumental variable (IV)	Employment	Positive short-term effect on employment. Positive evidence on the impact of public subsidies on employment of start-ups as well as for the established firms that have been into business for more than five years.
Liu and Rammer (2016)	5000–8000 firms	Panel	2001–2014	Matching method	Innovation output, export	Positive effect of public innovation funding. Higher innovation output for both product and process innovation.
Ramajo et al. (2008)	163 regions of the European Union (EU)	Panel	1981–1996	Exploratory spatial data analysis (ESDA); OLS-White; ML-SAR (Lag)	GGDP growth per capita	Regions in countries that implemented Cohesion Policy had a higher conditional convergence rate of GDP per capita.
Rodríguez-Pose and Fratesi (2004)	Objective 1 regions, i.e. regions where GDP per capita is below the 75 % threshold of the EU average	Cross-section and panel data	1989–1999	Cross-section unconditional beta convergence analysis	GDP per capita	Highest impact for support schemes that foster human capital and R&D and that target a more productive segment of enterprises.
Srhoj and Walde (2020)	361 treated Croatian firms	Panel	2009–2014	Difference-in-differences (DID)	Exporting activity, value added, employment	Public funds have a positive effect on exports in the introduction of new products, or existing products. A positive effect was also found for value added. No effect on employment.
Srhoj et al. (2019)	18,321 Croatian firms	Panel	2008–2012	Propensity Score Matching, Difference-in-differences (DID), Causal mediation analysis	Survival, sales, value-added, capital, employment, labour productivity	Positive effects on the outcome of interest for SMEs but no effects on larger firms.
Vicente and Kitsing (2015)	2709 companies from Estonia	Panel	2007–2012	Propensity Score Matching	Sales revenue, export revenues, gross profits, and value added per employee, value added per employee	Grant receiving companies' employment, sales and profitability indicators improved significantly relative to the control group. No firm evidence on grant related positive export or value added outcomes, shown in export sales per employee. The effect of grants on value added per employee also had some negative estimates.
Vildo and Masso (2009)	7263 Estonian companies	Panel	2002–2003	Propensity score matching with kernel and nearest neighbour method	employment, sales, capitalisation and survival rate	There was a positive effect of 21–25 % on employment and 31–44 % on sales within 2–3 years from treatment, where the positive productivity effect in value added per employee arose only by the third year from treatment and ranged between 53 % and 71 % depending on the matching method.

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Simona Ferraro is an economist. She received her doctorate in economics from Tallinn University of Technology where she is currently Senior Lecturer at the Department of Economics and Finance. Her research interests include economics of education, labor economics, innovation and efficiency analyses. She has published several articles in academic journals, including, among others, Applied Economics, Computers & Education.

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Helery Tasane is an Early Stage Researcher at Tallinn University of Technology. Her research topic focuses on the impact of institutional factors in achieving knowledge-intensive economies. In her research, Helery uses mainly microdata and microdata suitable empirical methods.

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Period	Educational institution	Field, degree
2017–2023	Tallinn University of Technology	Economics and Finance, PhD
2015–2017	Tallinn University of Technology	Applied Economics, MA

Language competence

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Estonian	Native
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German	Basic skills
Russian	Basic skills

Special Courses

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05.2019	Econometric Modelling in R (basic course)	I. Seppo (University of Tartu)
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09.2018	Panel data econometrics	S. Bond (CEMFI Summer School)

Professional employment

Period	Organisation	Position
2022–…	Enterprise Estonia	Head of Strategy and Analysis Department
2021–2022	Enterprise Estonia	Lead Analyst
2019–2022	Tallinn University of Technology	Programme Director
2017–2022	Tallinn University of Technology	Early Stage Researcher
2015–2017	Coca-Cola Hellenic Bottling Company	Baltic Investment Analyst
2014–2015	Coca-Cola Hellenic Bottling Company	Baltic Junior Commercial Analyst

Publications

Tasane, H.; Srun, S. (2023). The Institutional Environment, Human Capital Development and Productivity-Enhancing Factors: Evidence from ASEAN Countries. *TRaNS Trans-Regional and -National Studies of Southeast Asia*, 1−16. DOI: 10.1017/trn.2022.13. (ETIS 1.1.)

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Masso, J.; Männasoo, K.; Tasane, H. (2020). Euroopa Liidu ettevõtlus- ja innovatsioonitoetused panustavad tootlikkuse kasvu ning hõivesse. *Riigikogu Toimetised*, 42, 159−164. (ETIS 1.3.)

Männasoo, K.; Tasane, H.; Viires, I. (2018). Eksport ja innovatsioon ettevõtetes: Euroopa siirderiikide võrdlev uuring. *Riigikogu Toimetised*, 37, 125−134. (ETIS 1.3.)

Männasoo, K.; Rungi, M.; Hein, H.; Tasane, H. (2018). Ettevõtete investeerimismustrid ja roll globaalses väärtusloomes. *Riigikogu Toimetised*, 37, 111−124. (ETIS 1.3.)

Mannasoo, K.; Rungi, M.; Hein, H.; Tasane, H. (2018). Value Chain from Good to Great: Multiple-case Study of Estonian Companies. *2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*. IEEE, 1274−1278. DOI: 10.1109/IEEM.2018.8607437. (ETIS 3.1.)

Honours and Awards

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Saksa keel	algtase
Vene keel	algtase

Täiendkoolitus

Periood	Koolitus	Õppejõud ja haridusasutus
11.2019	Selected Topics in Panel Data Econometrics	A. Võrk (University of Tartu)
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Teenistuskäik

Periood	Organisatsioon	Ametikoht
2022–…	Enterprise Estonia	Head of Strategy and Analysis Department
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2014–2015	Coca-Cola Hellenic Bottling Company	Baltic Junior Commercial Analyst

Publikatsioonid

Tasane, H.; Srun, S. (2023). The Institutional Environment, Human Capital Development, and Productivity-Enhancing Factors: Evidence from ASEAN Countries. *TRaNS Trans -Regional and -National Studies of Southeast Asia*, 1−16. DOI: 10.1017/trn.2022.13. (ETIS 1.1.)

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Masso, J.; Männasoo, K.; Tasane, H. (2020). Euroopa Liidu ettevõtlus- ja innovatsioonitoetused panustavad tootlikkuse kasvu ning hõivesse*. Riigikogu Toimetised*, 42, 159−164. (ETIS 1.3.)

Männasoo, K.; Tasane, H.; Viires, I. (2018). Eksport ja innovatsioon ettevõtetes: Euroopa siirderiikide võrdlev uuring. *Riigikogu Toimetised*, 37, 125−134. (ETIS 1.3.)

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