Linking Innovation Systems, International Integration, and Investment Climate to Firm Productivity in Developing Countries

Mahyar Adibi and Keun Lee

This paper analyzes the importance of investment climate (IC), international integration (II), and innovation system (IS) variables on firm productivity. These variables are measured at the firm, sector, and country levels. It also investigates the interaction effects among them. Multilevel-mixed effect analysis is conducted using the World Bank Enterprise Survey data for 20 developing countries in 21 sectors. Results indicate that firm-level variables tend to be more robust than sector- or country-level variables and that more II variables are shown be significant than either IC or IS variables. Specifically, sector-level II variables are significant, whereas sector-level IC variables and sector-level R&D variables are insignificant. Sector-level IC and IS variables become significant only when they interact with firm-level variables. The results underscore the importance of firm-level capabilities, which can be enhanced by II (e.g., firm-level learning by exporting and Foreign Direct Investment [FDI] arrangement) and IS (e.g., firm-level education and training) as well as by spillover from sector-level II and human capital. Results also reveal the channels through which IC may affect firm productivity. IC exhibits an effect on firm productivity when it interacts with firm-level capabilities and activities.

Keywords: Firm productivity; Innovation systems; Investment climate; International integration; Multilevel analysis; Developing country.

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I. Introduction

Firms in the private sector are engines of economic development. Therefore, factors determining firm performance are important in the study of economic development. Previous studies identified the roles and importance of three main factors in firm performance, namely, investment climate (IC), international integration (II), and innovation systems (IS).

The World Bank (2005) defines IC as the policy, institutional, and regulatory environment in which firms operate. The concept of IC is closely related to what some authors in literature call "institutions" (Acemoglu *et al.*, 2001; Knack & Keefer, 1995) or "social infrastructure" (Hall & Jones, 1999). Many studies have considered the differences in economic institutions as the major source of cross-country differences in economic growth and prosperity (Acemoglu *et al.*, 2001; Rodrik *et al.*, 2004). Good-quality IC reduces transaction costs and leads to the reduction in investment uncertainty. This effect is attributed to the tendency of low-quality IC and high-regulatory environments to cause trade frictions and various transaction costs, which consequently reduce the magnitude of incentives for firms to invest (Anokhin & Schulze, 2009; The World Bank, 2005). Thus, the competitiveness of economies and their products is lowered (Escribano *et al.*, 2010). While the institutional supremacy or IC-oriented view flourished in literature, the present paper will examine its importance in an integrated framework which also considers other important factors, such as firm-level capabilities through diverse learning channels arranged by II and/or IS.

Latecomer firms in developing countries lack sufficient capability to innovate and create knowledge. Thus, these firms are highly dependent on technologies and practices developed by other countries. Several channels through which technologies are transferred and learning is made possible for latecomers have been identified in literature, and they are mostly through II, such as learning by exporting (LBE) (Clerides *et al.*, 1998) and learning through FDIs (Blomstrom & Kokko, 1997). The presence of FDI provides a condition through which local firms gain access to knowledge. LBE is an efficient way to learn from foreign customers and rivals. It induces productivity gains when firms upgrade product quality, innovate, and invest in marketing.

Although access to knowledge by II is indispensable, it is often insufficient for upgrading in value chains and eventually, in-house innovation. Thus, another important condition to consider is the Schumpeterian concept of IS, which is conceived and measured at the country, sector, and firm levels. Lundvall (2010) defines the national IS as the "elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge." IS is a concept related to the efficiency of producing, diffusing, and using knowledge in the firm, sector, and country levels. Scholars from the Schumpeterian school, such as Lundvall (2010) and Fagerberg (2005), advocate the concept of national innovation systems (NIS) and argue that the differences among the NIS of countries cause the differences in innovation and economic performances of these countries. Lee (2013b) measured IS at the firm, sector, and country levels, and verified its importance in the performance of firms, sectors, and nations.

The current study investigates the importance of IC, II, and IS at the firm, sector, or country level. Although the role and importance of IC, II, and IS have been elaborated in the literature, this study investigates the importance of these factors in a single framework and at the three levels. The latter is the current study's attempt to contribute to existing literature. The three factors are measured and compared at the firm, sector, and country levels, while considering the mutual interactions among them at different levels. Firms are influenced by the framework condition within which they perform. Examining the influence of environmental factors on firm-level resources can answer several questions. Under which conditions do poor IC cause productivity problems at the firm level? Under which conditions can firms gain from highly open or R&D-intense economies? Are firms with different capabilities variably influenced by framework conditions? These questions may lead to several interesting hypotheses, such as follows: although IC at the country-level influences firm performance, firm- or sector-level capabilities and learning in production require joint consideration and thus enhancement by establishing access to foreign knowledge through FDI or export (*i.e.*, II variables). The next step is to focus on the high level of capabilities, namely, innovation, by enhancing IS at the firm, sector, and country levels, thus improving the assimilation, diffusion, and creation of knowledge.

This study uses the IC survey conducted by the World Bank in 21 developing countries (Brazil, Chile, Costa Rica, Ecuador, Egypt, El Salvador, Guatemala, Guyana, Honduras, Madagascar, Mauritius, Montenegro, Morocco, Nicaragua, Oman, Pakistan, Serbia, South Africa, Sri Lanka, Vietnam, and Zambia) and classified into 20 different sectors that covered a total of approximately 6,523 manufacturing firms. The survey includes as many as 515 diverse variables, most of which can be measured at the firm, sector, and country levels. Thus, a multilevel mixed-effect analysis can be conducted (Goedhuys & Srholec, 2015; Hox, 2010; Lindley & Novick, 1981). This data structure is conventionally studied by moving variables to one single level through aggregation and disaggregation. However, this approach causes several statistical and conceptual problems (Hox, 2010).[1] Therefore, the current study adopts the multilevel mixed-effect technique to address these problems, although country-level results should be interpreted cautiously given the limited number (or only 21) of countries included in the sample.

Several studies use both the World Bank dataset and the multilevel models. However, these studies either investigate the effects of country-level institutions on firm performance (Dyke *et al.*, 1992; Goedhuys & Srholec, 2015; Lorenz, 2012; Srholec, 2011) or the interaction between institutions and firm-level resources (Barasa & Voeten 2015). In addition, compared with Lee and Temesgen (2009) whose focus lies on firm-level variables, the present study is comprehensive because it

[1] For example, when aggregation (Démurger, 2001; González-Pernía & Peña-Legazkue, 2015; Vohra, 2001) is used, a considerable amount of information is lost, and statistical analyses lose power. When disaggregation (Hallward-Driemeier *et al.*, 2006; Sternberg & Arndt, 2001) is employed, a few data values from a small number of super units transform into numerous data values for a large number of subunits, which cause significant but erroneous results (further discussed in Section 3.4).

compares the relative importance of IC, II, and IS at the firm, sector, and country levels and determines their interactions.

The analysis of the impacts of variables at different levels in this paper suggests, among others, the importance of the firm level variables, especially II variables. This idea implies that policy makers need to focus on fostering firm-level capabilities before or at least together with sector- or national-level factors of IC, IS, or openness. The importance of several interactions among the three factors and levels is also confirmed, such as mutual reinforcement of ICs and firm-level capabilities, NIS and firm-level capabilities, and interaction of LBE with national-level IS of higher R&D intensity.

This study is organized as follows. Section 2 discusses the existing literature and introduces the hypotheses based on the limitations identified from existing studies. Section 3 describes the data and variable construction as well as explains the empirical methodologies and models. Section 4 discusses the results after verifying each hypothesis. Section 5 provides the summary and concluding remarks, including policy implications.

II. Literature and Theoretical Perspectives

To understand the importance of the factors, the literature on each factor is reviewed to determine the direction and mechanism of their effects, considering that their influence can differ at the firm, sector, and country levels. Each section is summarized by identifying the limitations in the literature.

A. Investment climate

Stern (2002) defines IC as the policy and the institutional and behavioral environment, both present and expected, which influence the returns and risks associated with investment. The World Bank (2005) defines IC as the policy, institutional, and regulatory environment in which firms operate. Based on both definitions, IC is the set of location-specific factors that create opportunities and incentives for firms to invest and grow. IC can be conceived in two dimensions, namely, soft infrastructure and physical infrastructure. The former refers to the economic environment characterized by the institutional and political situation of a country (Acemoglu *et al.*, 2001; Hall & Jones, 1999), whereas the latter pertains to the basic physical structures, services, and facilities necessary for enterprises to operate (Bah & Fang, 2011; Dethier *et al.*, 2011; Dollar *et al.*, 2005; 2002; Kinda, 2010; Kinda *et al.*, 2011).

IC influences firm performance through transaction costs. Good IC removes unnecessary costs and risks and reduces investment uncertainty. Poor physical infrastructures limit transportation and trade services, increase logistics costs, and reduce the competitiveness of products (Escribano *et al.*, 2010). Similarly, low-quality soft infrastructure indirectly raises costs. Highly regulatory environments and macroeconomic instability cause friction, challenges, and various transaction costs, which consequently reduce the magnitude of incentives for firms to invest (Anokhin & Schulze, 2009; The World Bank, 2005).

Studies utilized diverse empirical approaches to investigate the effect of IC on the economic performance of firms and produced diverse results. Dollar *et al.* (2005) examined the influence of physical infrastructure (power loss, days to obtain a phone) and social infrastructure (custom day export, overdraft facility, and custom day import) for Bangladesh, China, India, and Pakistan on various dependent variables. The results show that IC influences productivity, wages, profit rates, growth rate of output, and employment at the firm level in the garment sector. However, Hallward-Driemeier *et al.* (2002) found no evidence that physical infrastructure (power outages, loss of sales due to transport) is significant for firm productivity and sales growth in China.

Several gaps were identified in the literature. First, the literature did not consider firm heterogeneity (in their levels of capabilities) in studying the effect of IC on firm performance. Only a few of the studies considered firm ecology, such as Sleuwaegen and Goedhuys, (2002). Second, the mechanisms through which IC factors cause friction and costs to firms were disregarded. Third, the effects of the business environment often differ by specific contexts (Easterly *et al.*, 1993). Firms in different sectors will be affected variably, and sensitivity to IC quality differs across sectors. Thus, introducing sector-level heterogeneity to the model is critical. Few studies considered this fact and attempted to use only dummy variables for sectors. However, dummy variables, which will be discussed in the methodology section, cannot properly represent this aspect in the model. Fourth, some of the literature did not jointly address the importance of IC and other environmental factors, such as II and IS. Finally, most authors constructed IC variables by using survey data, which use subjective variables. These types of variables can cause endogeneity problems. For example, profitable firms may have good connections with government officials and may therefore systematically face government harassment (Romp & De Haan, 2007). To overcome this problem, IC should be considered an environmental factor and is thus studied at the sector and country levels in the current study.

B. International integration

National economies work in the global system. Countries rely on one another for technology transfer and share knowledge on manufacturing methods, modes of organization, marketing, and product design. The present literature emphasizes several channels through which technologies are transferred and learning is made possible for latecomers, namely, imports of intermediate goods (Coe & Helpman, 1995; Feenstra & Markusen, 1994), learning by exporting (Clerides *et al.*, 1998), and learning through FDIs (Blomstrom & Kokko, 1997).

LBE (learning by exporting) refers to a variety of mechanisms that may induce productivity gains when firms start exporting, such as investing in marketing, upgrading product quality, innovating, or dealing with foreign buyers. Various studies found evidence supporting LBE. For example, Martins and Yang (2009) as well as Lee and Temesgen (2009) found evidence of performance improvement for exporters in developing countries. Van Biesebroeck (2005) analyzed data collected from 1992 to 1996 from nine sub-Saharan African countries and identified higher labor productivity for exporters than for non-exporters. However, some studies did not obtain supporting evidence for the LBE hypothesis. In a survey on international trade and technology diffusion, Keller (2004) concluded that evidence from econometric studies is scarce. Wagner (2007) presented strong evidence for the self-selection mechanism across a wide range of countries and sectors and found that exporting does not enhance productivity.

The literature emphasizes FDI as another channel for technology transfer and learning for less developed countries (LDCs) (The World Bank, 2003). Wang (1990) identified that an increase in FDI induces additional investments in human capital, which enhances the catch-up potential of the recipient country. Glass and Saggi (2002) determined that technology spillovers occur through the labor turnover from MNEs to local firms. They determined that product imitation by local firms in an LDC is possible only when foreign-invested firms create products within a country. However, empirical evidence exhibited ambiguous results. Rhee *et al.* (1990) claimed that engagement in a foreign market is largely responsible for the creation and subsequent growth of locally owned textile firms in Mauritius and Bangladesh. Other scholars found otherwise. For instance, Germidis (1977) examined a sample of 65 multinational subsidiaries in 12 developing countries and obtained nearly no evidence, whereas Haddad and Harrison (1993) determined negative spillovers associated with FDI in Morocco.

Several gaps in the literature on II are as follows. First, in the case of developing countries, the plausible question one can ask is,"what is the required and necessary condition under which firms are able to realize, absorb, and utilize knowledge available through export or FDI?" Despite the existing research on the role of absorptive capacity at the firm level, empirical studies on developing countries are limited. Second, the effect of FDI and export should be studied on the basis of the heterogeneity of firms in different sectors. Firms in technology-intensive sectors may be affected by FDI, or firms in labor-intensive sectors may learn more from export compared with high-tech sectors. Therefore, introducing firm heterogeneity to the model is essential. Finally, determining the joint importance of global engagement with other conditions of the firm's framework (*e.g.*, IS and IC) has crucial policy implications.

C. Innovation systems

IS is a framework for understanding innovation. This system can be understood on three levels, namely, on the country level as NIS, on the sector level as sectoral IS, and on the firm level as corporate innovation systems (CIS) as proposed by Lee (2013b). Apart from Lundvall (2010), Nelson and Rosenberg (1993) define IS as "a set of institutions whose interactions determine innovative performance of national firms." At the sector-level discussion of the sectoral systems of innovation, the concept of technological trajectories, which implies the importance of the direction of technology development and the sector in which innovations occur, has received attention in literature. Malerba and Orsenigo (1997) proposed that a sectoral system is a set of products and the set of agents carrying out market and non-market interactions for the creation, production, and sale of those products. A sectoral system also has a specific knowledge base, technologies, inputs, and demand. At the firm level, IS is called CIS, which is defined by Granstrand (2000: 13) as the set of actors, activities, resources, and institutions and the causal interrelations that are important for the innovative performance of a corporation. Effectiveness of CIS would be affected by the skill base of a firm, its internal technological efforts, and its linkages with external sources of knowledge (Lall, 1992). This concept was also studied under several topics, such as the absorptive capability of firms (Cohen & Levinthal, 1990; Easterby-Smith *et al.*, 2008; Zahra & George, 2002), firm-level learning (Jensen *et al.*, 2007; Nonaka *et al.*, 2000; Senge & Sterman, 1992), R&D, and human capital (Scherer, 1965; Teece, 1982).

The existing literature identified the main role of the three levels of IS as knowledge spillover and learning. Knowledge is tacit (Polanyi, 1967), which means it is less patentable and less transferrable (Evenson & Westphal, 1995; Lall, 2000). In a high-knowledge-spillover society, the probability that an innovation by one firm will be imitated by its competitors is high. However, these conditions will consequently reduce the propensity of competing firms to invest in R&D (Spence, 1984) .

The literature on IS suffers from several limitations. First, the IS concept originated from the context of developed countries, which significantly differs from that of developing countries. The concept of new structural economics by Lin (2012) emphasizes that a development policy should consider the structural differences between developed and developing countries (Lin & Monga, 2010). For example, focusing solely on R&D investment in developing countries is not entirely applicable (Bell & Pavitt, 1997). The problem in developing countries is about not less or more R&D but "zero" R&D (Lee, 2013a). Therefore, considering non-R&D factors, such as human capital, is also appropriate in the context of developing countries. Second, IS emphasizes the system approach, which means that the interactions and interfaces between various actors and the workings of a holistic system are important (Edquist, 1997; Lundvall, 2010). In the system approach, the implicit presumption is that the capability of firms and other economic actors is already high and sufficient for production and innovation. However, this presumption is often invalid in developing countries where capabilities are limited. Thus, Lee (2013a) highlighted the concept of capabiliy failure. Finally, determining the relative importance of each level of IS factor is crucial to justify development policies, which are currently under-addressed in the literature.

D. Discussion of hypothesis

Private firms are the engines of economic development, and their productivities are the sources of income growth of involved economic actors and of taxes for economies and therefore, welfare systems. Firm productivity is determined not only by firm-level factors but also affected by sector- and country-level factors. Although these three levels of factors can be considered for each IC, II, and IS, not much logic is required to hypothesize that firm-level factors are more direct and binding factors for firm-level productivity than sector- or country-level factors which are indirect despite their importance. IC is important for the various reasons noted above, although it would be useless if no firm uses better IC. Moreover, the extent to which IC would be useful should depend on the firm's capability to take advantage of better or worse IC. Some examples show that investment and firm growth happen even under poor IC.

One example is Ethiopia (Glans, 2014). Despite poor roads, limited electricity supply, and a rank of 127 out of 185 countries in the Doing Business Index, Ethiopia still attracted FDI from a number of Chinese firms, which contributed to the country's learning, firm growth, and economic growth. The investors mainly come from the manufacturing sector and consist of textile garment and shoe manufacturers, such as Huajian Group's shoe company, which opened a factory in Addis Ababa in 2012.[2] The Chinese firms contributed to the learning and labor quality in Ethiopia, as Chinese workers were brought over to train the Ethiopians in making high-quality shoes and then left when the Ethiopians were sufficiently skilled. A total of 69 percent of the Chinese companies provided formal training programs for workers, and approximately 11,314 Ethiopian laborers participated in Chinese-led training programs. Thus, employment size has increased by 19 percent since 2008 (The World Bank, 2012). Meanwhile, the share of agricultural output in Ethiopian GDP decreased from 66 percent in

[2] Huajian Group is based in Dongguan, Guangdong Province. It produces nearly 20 million pairs of shoes annually for global shoe brands such as Tommy Hilfiger, Guess, Naturalizer, and Clarkes (Glans, 2014).

1991 to 45 percent in 2011, a reduction that can be considered evidence of structural change (Lin, 2012).[3]

Another example is Bangladesh, whose infrastructure is one of the most underdeveloped in the world, a disadvantage that has prevented its economic growth. The country's infrastructure competitiveness was ranked 126th out of 133 countries, the lowest among South Asian countries. It also ranked 128th in competitiveness in electricity supply (Porter *et al.*, 2000). Despite these rankings, the Bangladesh garment sector grew because of the FDI made by Daewoo of Korea (Desh-Daewoo) and others. Over 130 Bangladeshi workers were trained in Korea; 115 of them left the company following an end-of-agreement with Desh-Daewoo and established their own garment-exporting firms. Consequently, the sector grew from a handful of factories in 1979 to more than 700 exporters by 1985 (Rhee *et al.*, 1990).

The importance of firm-level factors can also be discussed in terms of the literature on IS. The innovative performance of countries largely depends on the manner by which the actors of IS *relate* to one another as elements of a collective system of knowledge creation. For example, public research institutes, academia, and sectors serve as research producers carrying out R&D activities (OECD, 1997). In this context, different innovative actors must have strong linkages with one another to promote innovation, and governments should promote and activate relationships and cooperation among different innovation actors. In developing countries, the situation is different. Although developing countries also suffer from system failure of low interaction among key actors, a more serious problem is the low level of capability of the actors itself (Lee, 2013b); thus promoting innovation should primarily involve cultivating the capability of firms.

A similar reasoning also applies to the literature on II, especially if we follow the idea of the global value chain (GVC) (UNCTAD, 2013), which emphasizes the eventual upgrading of firms through II (exporting and FDI). The GVC perspective proposes that firms should climb the GVC ladder toward higher industrial sophistication and higher-end segments by intensifying learning by doing, exporting, and working together

[3] Structural change can be described as the reorganization of labor from low-productivity sectors to high-productivity economic activities. In most developing countries, this shift can entail changing labor from agriculture to manufacturing and modern services.

with foreign firms and personnel. Some cases support our argument. For instance, the Colombian flower sector began in 1969 with a joint investment by Floramerica, an American investor. The production and marketing methods of Floramerica were copied by another successful company, which was facilitated by the movement of key staff who embodied the knowledge accumulated at Floramerica. By 1990, Colombia had approximately 250 flower export firms (Rhee *et al.*, 1990). Thus, we start by hypothesizing that II is more important than IS or IC primarily because learning at the firm level often happens first by II, such as exporting, FDI, or licensing, before their own R&D efforts that often happen later, as is discussed in Chung and Lee (2015) from the past experience of Korea.

Latecomer firms in developing countries lack their own stocks of knowledge and skill and are thus highly dependent on the knowledge, technologies, and practices that have already been developed by other countries. Among the learning channels, FDI and exporting tend to precede learning by in-house R&D. The presence of FDI provides an important channel through which local firms gain access to foreign knowledge. In addition, LBE is an efficient way of learning from foreign customers and rivals. It induces productivity gains when firms learn about the production process and upgrade product quality, and the stage for their own innovation comes later. These learning channels often operate even under the poor IC noted above. Therefore, we hypothesize the higher importance of II compared with IS or IC.

Then, a remaining issue is the nature and importance of the diverse combination of interaction among II, IS, and IC at different levels. For instance, one may wonder about the circumstances under which poor IC causes a problem in the operation and learning of firms, as well as the conditions under which firms gain more from high R&D-intensity or higher openness of an economy. One may also wonder whether firms with different capabilities receive the same or different benefits from the same national-level IS, II, or IC. The answers to these questions form the argument for our final hypothesis. A simple version of our reasoning is that firms with high-quality capabilities enjoy additional benefits in productivity from the framework within which they operate. Conversely, one may reason that firms achieve lower productivity if they are located in a low-quality IC. For example, firms with high-quality labor capital as well as educated and trained staff and managers can benefit more from a high R&D-intensity of a sector or economy. In addition, a high R&D-

intensity society can boost firm performance through the increased effectiveness of LBE at the firm level. We can likewise consider that firms engaged in II are more exposed to an infrastructure condition, such that an undeveloped soft infrastructure negatively influences the effects of LBE and FDI on firm productivity.

III. Data, Variables, and Methodology

In this study, data were extracted from the most comprehensive firm survey conducted by the World Bank, namely, the Productivity and Investment Climate Survey. The survey covers a broad range of business environment topics, including access to finance, corruption, infrastructure, crime, competition, and performance measures. This standardized survey permits national and international comparisons of productive performance for different manufacturing sectors.

Some empirical studies used sales growth to measure a firm's performance in market share. The value chain perspectives of firm consider diverse activities involved in the supply of goods and services (including intangible phases such as flows of information, learning, or technological capabilities). This perspective seeks to discover whether firms ascend to a higher level of engagement in the GVC. This ascension can happen by increasing productivity, consequently increasing the value that a firm can add to its production. Thus, in this study, we measure performance, as a dependent variable, by either sales per worker or labor productivity rather than by sales growth (calculated as natural log in the analysis). Another merit of using labor productivity is that it is easily measured and readily comparable across countries.

Some variables are compound indicators; to construct these indicators, we used principal component analysis[4] (PCA). The Kaiser–Meyer–Olkin (KMO)[5] test was used to check the data qualification

[4] Principal component analysis (PCA) reduces the dimension of information. Through this technique, we used an orthogonal transformation to convert a set of observations into a lower dimensional picture and overcome the multicollinearity problem. The number of components is less than or equal to the number of original variables. In the current study, the component with an eigenvalue greater than 1 is used in the regression analysis.

[5] KMO measures the sampling adequacy for PCA. It has a scale between 0 and 1, with small values indicating that, overall, the variables have too little in common to warrant a PCA (Kaiser, 2002).

for PCA as shown in Appendix Table 2, for firm-level, sector-level, and country-level variables. In the following section, we describe the variables within each group used in this study. To overcome missing data, the multiple imputation technique was also applied. Appendix Table 1 provides some descriptive statistics, and Appendix Table 3 presents the correlation matrix for the variables used in our regressions.

A. Firm-level variables

We have two categories at the firm level: II and IS.

International integration has two indicators: (1) Export (share) is measured by the percentage of sales that a firm exports. We also examine export as a dummy variable, as it indicates whether a portion of the production or sales that a firm exports is made entirely domestically (Export [dummy] in the table). This indicator will help us discover the extent to which export contributes to firm productivity. (2) FDI is constructed as a dummy variable. If foreigners have more than 20 percent of the total stock of firms, then, the variable value is 1; otherwise, the variable value is 0.

Innovation system at the firm level has two indicators. (1) In-house R&D indicates whether a firm conducts R&D or not. It is defined by a dummy variable, which is equal to 1 if a firm invests in R&D; otherwise, 0. (2) LaborQ is a compound indicator involving human capital quality or non-R&D basis capability. It consists of three variables. (a) *Trained labor* is defined as a dummy variable equal to 1 if a firm provided training for labor; otherwise, 0. (b*) Educated labor* is measured as the percentage of labor with a secondary education. (c) *Trained manager* is defined as a dummy variable equal to 1 if a manager has some university training; otherwise, 0. Using these three variables (a, b, and c), we conduct the PCA technique, and the component with an eigenvalue greater than 1 (score) is used in regression analysis as LaborQ indicator.

Capital per worker (CapitalW) is added as a control variable, measured by the net book value of machinery and equipment in US dollars divided by the average number of workers.

B. Sector-level data and variables

Table 1 presents the observations classified into 20 sectors. At the sector level, all three major categories, IS, II, and IC, are included. The elements of each category are described in the following.

Table 1
Sector classification

	Sector	Freq.	Percent
1	Textiles	797	12.22
2	Leather	309	4.74
3	Garments	1.127	17.28
4	Agriculture	121	1.85
5	Food	970	14.87
6	Beverages	40	0.61
7	Metals and machinery	720	11.04
8	Electronics	191	2.93
9	Chemicals and pharmaceutics	561	8.6
10	Construction	8	0.12
11	Wood and furniture	614	9.41
12	Non-metallic and plastic materials	356	5.46
13	Paper	87	1.33
14	Sport goods	43	0.66
15	IT services	182	2.79
16	Other manufacturing	168	2.58
17	Retail and wholesale trade	4	0.06
18	Mining and quarrying	13	0.2
19	Auto and auto components	132	2.02
20	Other unclassified	80	1.23
	Total	6.523	100

Source: by the authors

Innovation systems consist of two major compound indicators. (1) Human capital encompasses three variables. (a) *Educated labor* is the percentage of firms in each sector within each country with labor that has a secondary education. (b) *Trained labor* indicates the percentage of firms in each sector within each country that provided training for their workers. Lastly, (c) *trained manager* signifies the percentage of firms in each sector within each country that has managers with some university training. Using these three variables (a, b, and c), we conduct the PCA technique, and the component with an eigenvalue greater than 1 (score) is used in regression analysis as Human capital indicator. Table 2 presents score factors for all compound indicators for each sector in our sample. It illustrates that high-quality laborers are working in the paper, beverages, auto and auto components, as well as metals and machinery sectors, whereas low-quality laborers are working in the electronics, textiles, and sporting goods sectors. (2) R&D capability encompasses two variables. (a) *R&D investment* indicates the percentage of firms in each sector within each country that invested in R&D and design. (b) *New product line* signifies the percentage of firms that introduced new product lines. Using these two variables (a and b), we conducted the PCA technique, and the component with an eigenvalue greater than 1 (score) was used in regression analysis as R&D capability indicator. As shown in Table 2, sectors with high R&D quality are electronics, retail and wholesale, and auto and auto components, all of which are relatively high capital-intensive sectors compared with others, such as textiles and garments (see Table 2).

Investment climate has two compound indicators. (1) Soft infrastructure is a compound indicator consisting of three variables. (a) *Custom and trade regulation* is the percentage of firms in each sector within each country that considered custom and trade regulation as major obstacles to their performance. (b) *Business licensing and permits* denotes the percentage of firms that considered business licensing and permits as major obstacles to their performance. (c) *Macro instability* represents the percentage of firms in each sector within each country that considered macroeconomic instability as a major obstacle to their performance. Managers in auto and auto components as well as construction sectors complained about the soft infrastructure framework. (2) Physical infrastructure consists of three indicators. (a) *Telecommunications* is the percentage of firms that considered telecommunications as a major obstacle to their performance. (b) *Electricity* pertains to the percentage of firms that considered electricity a major obstacle to their operations. (c) *Transportation* is the percentage of firms that considered transportation as a major obstacle to their operations. Similar to other compound indicators, both soft and physical infrastructure indicators are constructed using the PCA technique and are used as a representative indicator in regression analysis. The scores of the beverages and agriculture sectors indicate that these firms are sensitive to an undeveloped physical infrastructure (Table 2).

International integration has two indicators. (1) FDI is the percentage of firms with foreigners having more than 20 percent of ownership. (2) Export is the percentage of firms that export. The mining and quarrying sector show the highest share of FDI firms, followed by agriculture and beverage sector. Leather, sporting goods, and retail and wholesale trade

Table 2
PCA Score Value at Sector-level

Sector classification	Human capital Score	R&D capability Score	Social infra. Score	Physical infra. Score
Agriculture	0.557	0.182	0.060	0.769
Auto	1.013	0.600	2.381	-0.447
Beverages	1.254	0.271	-0.454	1.095
Chemicals and pharmaceutics	0.115	0.394	0.069	0.178
Construction	-0.382	-0.870	1.099	0.339
Electronics	-0.405	0.897	0.472	-0.147
Food	-0.057	-0.156	-0.495	0.043
Garments	-0.190	-0.263	0.332	-0.454
IT services	0.201	-0.738	-1.629	0.615
Leather	-0.233	-0.045	0.224	-0.346
Metals and machinery	0.688	0.188	0.120	0.319
Mining and quarrying	0.524	0.315	0.584	-0.410
Non-metallic and plastic materials	-0.029	-0.634	-0.499	0.151
Paper	1.267	-0.391	-1.324	0.599
Retail and wholesale trade	0.444	0.842	-1.020	-1.492
Sport goods	-2.623	-0.485	-2.652	-0.891
Textiles	-0.979	-0.035	0.030	-0.204
Wood and furniture	0.360	0.296	0.332	0.243
Other manufacturing	0.607	0.190	-0.414	0.540
Other unclassified	0.439	-	0.629	-0.622

Source: by the authors

sectors attracted the lowest amount. Firms in the garments, agriculture, leather, and food sectors are the main exporters. Technology-intensive sectors, such as chemicals and pharmaceutics, IT services, and construction, have the lowest amount of exports.

C. Country-level data and variables

Firms in our sample are located in 21 countries belonging to the low, lower-middle, and upper-middle income groups. Table 3 indicates the number of firms within each country. Similar to the sector-level variables, country-level variables have three main categories, namely, IS, II, and IC. The only difference is that country-level variables are calculated by the average of firms within each country.

South Africa and Brazil have the highest scores for R&D capability, but they do not have high human capital scores. Pakistan and Honduras score above other countries in the human capital index but

TABLE 3
COUNTRY-LEVEL

	Country	Freq.	Percent
1	Brazil2003	1,499	22.98
2	Chile2004	841	12.89
3	CostaRica2005	263	4.03
4	Ecuador2003	188	2.88
5	Egypt2004	674	10.33
6	ElSalvador2003	14	0.21
7	Guatemala2003	10	0.15
8	Guyana2004	127	1.95
9	Honduras2003	13	0.2
10	Madagascar2005	109	1.67
11	Mauritius2005	71	1.09
12	Montenegro2003	6	0.09
13	Morocco2004	693	10.62
14	Nicaragua2003	6	0.09
15	Oman2003	21	0.32
16	Pakistan2002	868	13.31
17	Serbia2003	56	0.86
18	SouthAfrica2003	382	5.86
19	SriLanka2004	388	5.95
20	Vietnam2005	158	2.42
21	Zambia2002	136	2.08

Source: by the authors

receive average scores in R&D capability. Nicaragua ranks first in FDI and exports. More than 30 percent of firms in Nicaragua receive FDI and over 60 percent export. In Vietnam, 50 percent of firms export a portion of their sales, but only 10 percent of firms receive foreign investment. Another interesting case is Zambia, an African country where 30 percent of firms have foreign stockholders, nearly the same proportion of firms with export experience. Among the countries in our sample, Nicaragua has the highest number of firms disturbed by the poor condition of soft infrastructure, followed by Madagascar and Zambia. Honduras, Costa Rica, and Egypt have the highest scores for physical infrastructure, which indicate undeveloped infrastructure as a serious problem impeding the operations of firms. Table 4 presents PCA score values for all compound indicators at country level.

Table 4
PCA Score Value at Country-level

Country name	Human capital Score	R&D capability Score	Social infra. Score	Physical infra. Score
Brazil2003	-0.450	1.631	0.050	-0.283
Chile2004	-1.238	-0.826	0.155	0.849
CostaRica2005	-0.543	-0.554	0.068	1.582
Ecuador2003	-0.186	0.194	0.101	1.177
Egypt2004	-0.770	-3.000	0.047	1.398
ElSalvador2003	0.109	1.116	0.286	0.083
Guatemala2003	-0.999	0.548	0.200	0.819
Guyana2004	-0.140	-0.494	0.047	1.149
Honduras2003	0.829	-0.162	0.231	2.032
Madagascar2005	-1.695	-0.803	0.312	0.055
Mauritius2005	-0.544	0.273	0.070	-0.354
Montenegro2003	-0.272	-2.379	0.000	-1.000
Morocco2004	0.812	-0.327	0.141	-1.867
Nicaragua2003	0.802	-0.608	0.333	0.516
Oman2003	-0.499	-1.409	0.190	-2.032
Pakistan2002	3.111	0.078	0.013	0.282
Serbia2003	-0.880	-1.246	0.071	-0.415
SouthAfrica2003	-1.132	1.737	0.178	-0.576
SriLanka2004	0.228	0.017	0.173	-2.570
Vietnam2005	-0.592	0.276	0.101	1.360
Zambia2002	-0.868	0.403	0.309	0.647

Source: by the authors

D. Methodology and models

As a pioneer of resource-based view (RBV) of firms, Penrose (1995) focused on profit derived from using firm-level resources (capabilities) in the existing or new fields of businesses. She considered firms as a bundle of resources (competences) used for innovation, problem solving, and cumulative learning in profit making (Penrose, 1995; Rumelt, 1984; Wernerfelt, 1984). Nevertheless, Barney (1991), Teece (1982), and others specified that RBV is purely internally focused and disregards the external environment that can affect firm performance. To compensate for this deficiency, evolutionary economists (Dosi, 1982; Nelson & Winter, 2009) employed the dynamic approach toward firm theory; they regarded firm growth as a process emerging from the interaction between internal factors and external factors. Despite the multilevel attitude of evolutionary economists, a few empirical studies have appeared. In the meantime, several other approaches, such as endogenous growth models (Aghion *et al.*, 1998; Grossman & Helpman, 1991; Romer, 2007) or catch-up growth models (Abramovitz, 1986; Fagerberg *et al.*, 2004; Verspagen, 1991), focus on national-level factors. A multilevel approach is lacking in existing literature. The current study fills this gap.

In a hierarchal model, individuals are generally nested in a social context. Individuals and social contexts interact and influence one another. As such, a hierarchical system of individuals is nested within groups or contexts (Hox, 2010). In this system, variables can be defined at any level of the hierarchy and may proxy individuals and groups. This kind of system leads to multilevel research. Multilevel problems are conventionally studied by moving all variables found at different levels to a single level through aggregation or disaggregation. However, this approach is inadequate and can lead to some problems (Hox, 2010). If the analyst is not careful in interpreting the results, he or she may commit the fallacy of the wrong level, which involves analyzing the data at one level and formulating conclusions at another level. The most well-known fallacy is probably the ecological fallacy, which is interpreting aggregated data at the individual level. It is also called the "Robinson effect" after Robinson (2009). A suitable approach to observing multilevel data is realizing that data need not be analyzed at one level. Instead, all levels presented in the data are important in their own way.

A two-level structure is assumed with firms at level 1 and countries or sectors at level 2. A standard one-level regression model is given as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij}, \tag{1}$$

where y_{ij} is the dependent variable at the firm level, which is firm productivity in our study; X_{ij} is the firm-level explanatory variable; β_{0j} is the intercept; β_{1j} is the regression coefficient; and e_{ij} is the usual statistical error term. The subscript i is for the firm (i = 1...,n_j), and j is for the country or sector (j = 1...,n_i). If we move to the two-level regression models, then, their difference from the usual one-level regression model is that we assume each country or sector has a different intercept coefficient β_{0j} and a different slope coefficient β_{1j}. Error terms e_{ij} are assumed to have a mean of zero and a variance to be estimated. The intercept and slope coefficients are random variables that vary across countries and sectors. Thus, they are referred to as "random coefficients" with a certain mean value, variance, and distribution that can be explicitly modeled in a multilevel framework.

By constructing a multilevel model, we allow the firm-level relationships to differ by country or sector and explain the variance by introducing country and sector-level predictions. A two-level model with explanatory variables at the firm and country or sector levels thus emerges if intercept β_{0j} and slope β_{1j} are allowed to be random variables.

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + u_{0j}, \quad (2)$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}Z_j + u_{1j}, \quad (3)$$

where Z_j is the level-2 or country or sector explanatory variable, and u_{0j} and u_{1j} are normally distributed error terms for each country or sector and are assumed to be independent from the level-1 error e_{ij}. Thus, β_{0j} predicts the average outcome (Y) in a country by a level-2 variable (Z), and β_{1j} expresses that the outcome (Y) at the firm level depends on the relationship between firm-level factors (X_{ij} in Equation [1]) and country-level variables (Z_j in Equations [2] and [3]). In Equations 2 and 3, regression coefficients γ have no subscript j because they apply to all countries or are fixed coefficients.

Our model with explanatory variables at the firm and country or sector levels can be written as a single complex regression equation by substituting Equations 2 and 3 into Equation 1. Rearranging the terms gives

$$Y_{ij} = \gamma_{00} + \gamma_{01}Z_j + \gamma_{10}X_{ij} + \gamma_{11}Z_jX_{ij} + (u_{0j} + u_{1j}X_{ij} + e_{ij}). \quad (4)$$

The segment $(+ \gamma_{01}Z_j + \gamma_{10}X_{ij} + \gamma_{11}Z_jX_{ij})$ contains fixed coefficients and is thus often called as the fixed part of the model. The part in the parenthesis is called the random part of the model.

The presence of more than one residual term renders ordinary least squares inapplicable, and the estimator in multilevel regression analysis is the maximum likelihood estimator (Raudenbush *et al.*, 2002).

Our analyzing strategy involves four steps. In the first step, we estimate a model with no explanatory variables. This model is known as the intercept-only model. The intercept-only model, which is derived from Equations 1 and 2, is given in the following equation. If no explanatory variable X exists at the lowest level, then, Equation 1 is shortened to

$$firm\ performance_{ij} = \beta_{0j} + e_{ij}. \tag{5}$$

Similarly, if no explanatory variable Z exists at the highest level, then, Equation 2 is shortened to

$$firm\ performance_{ij} = \gamma_{00} + u_{0j}. \tag{6}$$

We can find the single equation model by substituting Equation 6 into Equation 5.

$$firm\ performance_{ij} = \gamma_{00} + u_{0j} + e_{ij}. \tag{7}$$

By using this model, we can define intra-class correlation ρ, which indicates the proportion of variance explained by the grouping structure in the population. The intra-class correlation can also be interpreted as the expected correlation between two randomly drawn units in the same group.

A model with all lower-level explanatory variables is estimated in the second step. This model is written as

$$\begin{aligned} firm\ \ performance_{ij} &= \beta_{0j} + \beta_{1j}Laborq_{ij} + \beta_{2j}InhouseR\&D_{ij} \\ &+\beta_{3j}\exp ort_{ij} + \beta_{4j}FDI_{ij} + \beta_{5j}Capitalw_{ij} + e_{ij}. \end{aligned} \tag{8}$$

To identify the extent to which the effects of firm-level factors differ by country and sector, we let intercept β_{0j} and the slopes of firm level variables β_{5j} become random (as indicated in Equation 9). We estimate this model for the country and sector group levels.

$$\begin{aligned} \beta_{0j} &= \alpha_{00} + u_{0j} \\ \beta_{1j} &= \alpha_{10} + u_{1j} \\ \beta_{2j} &= \alpha_{20} + u_{2j} \\ \beta_{3j} &= \alpha_{30} + u_{3j} \\ \beta_{4j} &= \alpha_{40} + u_{4j} \\ \beta_{5j} &= \alpha_{50} + u_{5j}. \end{aligned} \tag{9}$$

In the third step, we add higher-level variables to the basic model. Thus, the intercept and slope coefficients become functions of higher-level variables, and the higher-level section of the model becomes the following:

$$\begin{aligned}
\beta_{0j} &= \alpha_{00} + \alpha_{01}IS_j + \alpha_{02}II_j + \alpha_{03}IC_j + u_{0j} \\
\beta_{1j} &= \alpha_{10} + \alpha_{11}IS_j + \alpha_{12}II_j + \alpha_{13}IC_j + u_{1j} \\
\beta_{2j} &= \alpha_{20} + \alpha_{21}IS_j + \alpha_{22}II_j + \alpha_{23}IC_j + u_{2j} \\
\beta_{3j} &= \alpha_{30} + \alpha_{31}IS_j + \alpha_{32}II_j + \alpha_{33}IC_j + u_{3j} \\
\beta_{4j} &= \alpha_{40} + \alpha_{41}IS_j + \alpha_{42}II_j + \alpha_{43}IC_j + u_{4j} \\
\beta_{0j} &= \alpha_{50} + u_{5j},
\end{aligned} \tag{10}$$

where IC_j, IS_j, and II_j are variables that proxy IC, national IS, and II, respectively. Finally, the interaction terms between the firm and sector levels are examined. The overall model is given as follows:

$$\begin{aligned}
& firm\ \ performance_{ij} = \alpha_{00} + \alpha_{10}Laborq_{ij} + \alpha_{20}InhouseR\,\&\,D_{ij} \\
& + \alpha_{30}\exp ort_{ij} + \alpha_{40}FDI_{ij} + \alpha_{50}Capitalw_{ij} + \alpha_{01}IS_j + \alpha_{03}IC_j \\
& + \alpha_{01}(IS_j * Laborq_{ij}) + \alpha_{02}(II_j * InhouseR\,\&\,D_{ij}) \\
& + \alpha_{23}(IC_j * InhouseR\,\&\,D_{ij}) + \alpha_{31}(IS_j * \exp ort_{ij}) + \alpha_{32}(II_j * \exp ort_{ij}) \\
& + \alpha_{33}(IC_j * \exp ot_{ij}) + \alpha_{41}(IS_j * FDI_{ij}) + \alpha_{42}(II_j * FDI_{ij}) + \alpha_{43}(IC_j * FDI_{ij}) \\
& + (u_{4j} * FDI_{ij}) + (u_{0j} * Laborq_{ij}) + (u_{2j} * InhouseR\,\&\,D_{ij}) \\
& + (u_{3j} * \exp ort_{ij}) + (u_{5j} * Capitalw_{ij}) + u_{0j} + e_{ij}.
\end{aligned} \tag{11}$$

IV. Results and Discussion

A. Direct effects of firm-, sector-, and country-level variables

Table 5 presents the empirical results of intercept-only models. Coefficients simply demonstrate the average labor productivity across countries (4.5 USD per worker) and sectors (5.39 USD per worker). The variances of firm-level residual errors at the country and sector levels are estimated as 1.14 and 0.87, respectively. The variance of country-level residual errors is 0.32, and that of sector-level residual errors is 1.11. All estimated parameters are larger than the corresponding standard errors, and the calculation indicates that these parameters

Table 5

Determinants of Firm Productivity: intercept-only models

	Country model		Sector model	
Fixed part				
Intercept	4.505	(0.702)***	5.398	(0.559)***
Random part				
e	1.141	(0.181)***	0.872	(0.178)***
Intercept	0.328	(0.063)***	1.112	(0.056)***
# firms	6523		6523	
# country	21		-	
# sector	-		20	
ICC	0,223		0,560	

Source: by the authors

Note: Robust standard errors are in parentheses, *, ** , and *** represent 10%, 5% and 1% of significance, respectively.

are all significant. The intra-class correlations (ICCs) equal 0.23 and 0.56 for country and sector models, respectively. We can infer that 23 percent of the variance of firm productivity is explained at the country level, and 56 percent of the variance is explained at the sector level. These values are relatively high, requiring this data structure to be studied within a multilevel context.

Next, we consider a model with only firm-level explanatory variables. However, we allow the estimated intercept and slope coefficients of the firm-level variables to vary across countries and sectors by including the respective random effects. Despite the absence of country- or sector-level predictors, the random effects reveal the extent to which the intercept and firm-level variable influencing labor productivity differ by country and sector. Table 6 presents the results of this estimation. Models 1 and 2 vary across sectors, whereas Models 3 and 4 vary across countries. Models 2 and 4 are used as our ideal models. The coefficients of IS predictors (*i.e.*, labor quality and in-house R&D) are positive and statistically significant at the 1 percent level in the country- and sector-grouped models. The R&D slope coefficient denoted that firms investing in in-house R&D have 17 percent higher labor productivity than those not investing in in-house R&D across sectors (Model 2) and 21 percent higher across countries (Model 4). The labor quality coefficient denotes that an increase in labor quality by one standard deviation is associated with 12 percent and 11 percent increases in labor productivity in sector

TABLE 6

DETERMINANTS OF FIRM PRODUCTIVITY: FIRM-LEVEL FACTORS, ACROSS COUNTRIES AND SECTORS

		Grouped by country				Grouped by sector			
		Model 1		**Model 2**		**Model 3**		**Model 4**	
	Fix part								
f-IS	LaborQ	0.140	(0.042)***	0.119	(0.036)***	0.125	(0.036)***	0.110	(0.035)***
f-IS	In-house R&D	0.209	(0.072)***	0.170	(0.063)***	0.273	(0.040)***	0.214	(0.041)***
f-II	FDI	0.568	(0.114)***	0.493	(0.097)***	0.651	(0.096)***	0.572	(0.096)***
f-II	Export(share)	0.003	(0.001)**			0.005	(0.001)***		
f-II	Export(dummy)			0.434	(0.084)***			0.485	(0.072)***
	Capitalpw	0.002	(0.001)***	0.002	(0.001)**	0.000	(0.000)***	0.000	(0.000)***
	Sector dummy	Yes		Yes		-		-	
	Country dummy	-		-		Yes		Yes	
	Intercept	4.102	(0.684)***	3.987	(0.691)***	3.923	(0.097)***	3.855	(0.094)***
	Random part								
	LaborQ	-2.212	(0.343)***	-2.415	(0.392)***	-2.378	(0.391)***	-2.428	(0.408)***
	In-house R&D	-1.646	(0.359)***	-1.866	(0.471)***	-3.257	(2.328)	-2.951	(1.240)**
	FDI (20%)	-1.078	(0.290)***	-1.332	(0.329)***	-1.271	(0.461)***	-1.265	(0.429)***
	Export(share)	-5.421	(0.234)***			-5.603	(0.250)***		
	Export(dummy)			-1.311	(0.250)***			-1.458	(0.279)***
	Capitalpw	-5.688	(0.216)***	-5.645	(0.211)***	-11.121	(0.268)***	-11.150	(0.275)***
	Intercept	1.134	(0.155)***	1.145	(0.155)***	-1.042	(0.180)***	-1.085	(0.183)***
	e	0.187	(0.009)***	0.178	(0.009)***	0.209	(0.009)***	0.199	(0.009)***
	# firms	6219		6260		6219		6260	
	# Sector	-		-		20		20	
	# Country	21		21		-		-	

Source: by the authors

Notes: Robust Standard errors are in parentheses, *, ** , and *** represents 10%, 5% and 1% of significance, respectively.
f-IS stands for firm-level innovation systems category variables
f-II stands for firm-level international integration category variables

(Model 4) and country (Model 2), respectively. Capital per worker, which is included as a control variable, is positive and robustly significant across different models. In models grouped by country, a dummy variable for sector is included. A country dummy variable is also included in models that are grouped by sector.

The FDI effect is positive and significant. However, even with FDI contributing to firm performance by 49 percent across sectors, higher contributions are observed across countries by 57 percent. We thoroughly study the second channel of II exports. Two types of export indicators are used. The first is export as a percentage of sales, and the second is export as a dummy variable. Both variables, which proxy exports, are significant, indicating the contribution of II to firm productivity regardless of the degree of engagement. Exporters have 43 percent and 48 percent higher performance values across sectors and countries, respectively. However, the effect of change in export orientation is unremarkable at only 0.3–0.5 percent.

Subsequently, we add the country-level predictors to the intercept and slope coefficients of firm-level IS and II. Table 7 provides the

Table 7

Determinants of Firm Productivity: firm- and country-level factors

		Model 1		Model 2		Model 3	
	Fix part						
f-IS	LaborQ	0.140	(0.042)***	0.140	(0.042)***	0.139	(0.042)***
	In-house R&D	0.209	(0.072)***	0.209	(0.072)***	0.209	(0.072)***
f-II	FDI	0.568	(0.114)***	0.566	(0.114)***	0.569	(0.114)***
	Export(share)	0.003	(0.001)**	0.003	(0.001)**	0.003	(0.001)**
c-IS	Human capital	1.127	(0.668)*	1.084	(0.673)*	1.182	(0.675)*
	R&D capability	0.687	(0.567)	0.436	(0.601)		
c-IC	Physical infra.	-0.027	(0.543)	0.164	(0.512)		
	Soft infra.	-0.140	(0.505)	0.061	(0.540)		
c-II	Cexport	-0.046	(0.047)				
	CFDI			5.446	(6.983)		
	CapitalW	0.002	(0.001)***	0.002	(0.001)***	0.002	(0.001)***
	Intercept	5.599	(1.365)***	3.669	(1.182)***	5.260	(1.287)***
	Sector dummy	Yes		Yes		Yes	
	Random part						
	LaborQ	-2.212	(0.344)***	-2.210	(0.343)***	-2.214	(0.344)***
	In-house R&D	-1.646	(0.358)***	-1.648	(0.358)***	-1.648	(0.359)***
	FDI	-1.079	(0.290)***	-1.077	(0.290)***	-1.080	(0.290)***
	Export(share)	-5.425	(0.234)***	-5.423	(0.234)***	-5.423	(0.234)***
	Capitalw	-5.687	(0.216)***	-5.689	(0.216)***	-5.688	(0.216)***
	Intercept	1.030	(0.155)***	1.038	(0.155)***	1.063	(0.155)***
	e	0.187	(0.009)***	0.187	(0.009)***	0.187	(0.009)***
	# firms	6219		6219		6219	
	# Country	21		21		21	

Source: by the authors
Notes:
Standard errors are in parentheses, *, **, and *** represents 10%, 5% and 1% of significance, respectively
f-IS stands for firm-level innovation system
f-II stands for firm-level international integration
c-IS stands for country-level innovation system
c-IC stands for country-level investment climate
c-II stands for country-level international integration

results of firm and country levels in the two models. These results are placed in two separate models because of the high correlation between country-level exports and FDI. Firm-level IS and II remain positive and significant in both models. However, the results in the country level differ. Human capital is significant only at 10 percent, and the role of R&D is insignificant in developing countries.

At the country level, we also defined the IC factors as consisting of two main categories: soft infrastructure and physical infrastructure. We show that country-level IC variables are statistically insignificant (see Table 7), country-level II (*i.e.*, export and FDI) variables are insignificant, and country-level human capital variable is significant among country-level IS variables. These results are consistent with the reasoning that country-level variables are not as important as firm-level variables.

In the following step, we add all three categories of sector-level variables to the base models. Table 8 shows the results, which reveal that firm-level variables are significant across different models. The sector-level human capital variable is shown to be significant at the 1 percent level, whereas the sector-level R&D variable is insignificant to firm performance. The coefficients of the sector-level human capital variable imply that one standard deviation increase in human capital at the sector level leads to a 22 percent increase in labor productivity. The findings show that sector-level IC variables (physical and soft infrastructure) are insignificant, similar to the country-level results. However, unlike the country-level II variables, the sector-level II variables of export and FDI are significant. The coefficient of s-FDI (sector-level FDI) denotes that a 1 percent increase in the average number of firms with foreign ownership leads to a 9 percent increase in labor productivity (Model 2). The coefficient of s-export (sector-level export) denotes that a 1 percent increase in the average number of firms exporting their products leads to a 7 percent increase in labor productivity (Model 4).

Table 9 provides a summary of the results in Tables 6, 7, and 8 on the effects of IS, IC, and II on firm performance at the firm, sector, and country levels. The relative importance of factors can be evaluated from their significance at different levels. Both components of II (*i.e.*, export and FDI) show the same significant behavior at the firm and sector levels, but only one component of IS (*i.e.*, human capital) maintains its significant effect at the sector level. By contrast, none of the components of IC is significant at the sector level. The results

Table 8

Determinants of Firm Productivity: firm- and sector-level factors

		Model 1		Model 2		Model 3		Model 4	
	Fixed part								
f-IS	LaborQ	0.129	(0.036)***	0.132	(0.037)***	0.129	(0.036)***	0.132	(0.037)***
	In-house R&D	0.282	(0.038)***	0.271	(0.038)***	0.283	(0.038)***	0.270	(0.038)***
f-II	Export(share)	0.004	(0.001)***	0.004	(0.001)***	0.004	(0.001)***	0.004	(0.001)***
	FDI	0.600	(0.099)***	0.604	(0.099)***	0.611	(0.099)***	0.614	(0.099)***
s-IS	Human capital	0.223	(0.051)***	0.195	(0.050)***	0.226	(0.051)***	0.197	(0.050)***
	R&D capability	-0.066	(0.053)			-0.074	(0.053)		
s-IC	Soft infra.	-0.021	(0.034)			-0.024	(0.034)		
	Physical infra.	-0,058	(0.074)			-0,143	(0.074)**		
s-II	iFDI	0.092	(0.032)***	0.087	(0.032)***				
	iexport					0.076	(0.026)***	0.072	(0.025)***
	CapitalW	0.000	(0.000)***	0.000	(0.000)***	0.000	(0.000)***	0.000	(0.000)***
	Intercept	3.839	(0.121)***	3.838	(0.097)***	3.856	(0.123)***	3.838	(0.097)***
	Country dummy	Yes		Yes		Yes		Yes	
	Random part								
	LaborQ	-2.352	(0.388)***	-2.315	(0.375)***	-2.359	(0.387)***	-2.326	(0.374)***
	In-house R&D	-13.968	(5.076)**	-17.172	(4.177)***	-15.876	(5.547)***	-16.415	(5.442)***
	FDI	-1.228	(0.424)***	-1.227	(0.421)***	-1.222	(0.428)***	-1.223	(0.426)***
	Export(share)	-5.621	(0.252)***	-5.569	(0.249)***	-5.622	(0.249)***	-5.575	(0.247)***
	Capitalw	-11.146	(0.269)***	-11.107	(0.270)***	-11.136	(0.270)***	-11.100	(0.271)***
	Intercept	-1.169	(0.182)***	-1.145	(0.182)***	-1.151	(0.181)***	-1.135	(0.180)***
	e	0.207	(0.009)***	0.207	(0.009)***	0.207	(0.009)***	0.207	(0.009)***
	# firms	6219		6219		6219		6219	
	# Sectors	20		20		20		20	

Source: by the authors
Notes:
Standard errors are in parentheses, * , ** , and *** represents 10%, 5% and 1% of significance, respectively
f-IS stands for firm-level innovation system
f-II stands for firm-level international integration
s-IS stands for sector-level innovation system
s-IC stands for sector-level investment climate
s-II stands for sector-level international integration

seem to underscore the importance of II, in comparison with IS or IC. These results imply that firms in developing countries primarily need access to knowledge for their learning, which is possible through FDI and export. Moreover, at later stages, IS should be developed to promote assimilation, diffusion, and creation of knowledge within the society.

The summary in Table 9 is consistent with our hypothesis regarding the relative importance of different levels. None of the county-level variables are significant, whereas all the firm-level variables are

Table 9
Result summary

	Innovation System	International Integration	Investment Climate
	Human capital	Export	Soft infrastructure
	R&D	FDI	Physical infrastructure
Firm Level	○	○	-
	○	○	-
Sector Level	○	○	×
	×	○	×
Country Level	○	×	×
	×	×	×

Source: by the authors

significant, among IC or II variable. In IS variables, the insignificance of the sector-level R&D variable indicates the weak spillover from sectors to firms and the ineffectiveness or failure of the innovation system in developing countries. This finding is consistent with our reasoning that firms should receive the highest attention because the major obstacle for firms in developing countries is capability failure at the firm level.

B. Firm- and sector-level interaction model

Some questions remain unanswered. Based on the insignificant coefficient of IC, can we conclude that IC is inconsequential to firm performance? Can we conclude that a society with high R&D intensity does not affect firm innovation? These questions can be addressed by exploring the diverse framework condition within which a firm operates influences firm performance. To verify such conditions, we use a cross-level interaction analysis to investigate the interaction effects between sector- and firm-level variables, given the observed insignificance of most of country-level variables. Table 10 presents the results. First, the direct effect of the firm-level variables is also the same as those of the previous models without interaction terms, except for the soft and physical infrastructures. We do not consider these two factors

TABLE 10

DETERMINANTS OF FIRM PRODUCTIVITY: INTERACTION OF FIRM- AND SECTOR-LEVEL FACTORS

	Model 1		Model2	
Fix part				
Laborq	0.129	(0.035)***	0.134	(0.031)***
In-house R&D	0.290	(0.045)***	0.299	(0.045)***
FDI	0.168	(0.037)***	0.202	(0.041)***
Export	0.668	(0.100)***	0.616	(0.093)***
s-Human capital	0.192	(0.056)***	0.230	(0.055)***
s-Human capital*Laborq	-0.016	(0.025)	-0.025	(0.019)
s-Human capital*In-house R&D	-0.036	(0.036)	-0.040	(0.032)
s-Human capital*Export	0.045	(0.039)	0.049	(0.037)
s-Human capital*FDI	0.114	(0.072)	0.081	(0.071)
s-R&D capability	-0.110	(0.060)*	-0.096	(0.060)
s-R&D capability*Laborq	0.074	(0.030)**	0.103	(0.030)***
s-R&D capability*In-house R&D	-0.080	(0.047)*	-0.064	(0.048)
s-R&D capability*Export	0.131	(0.040)***	0.102	(0.041)**
s-R&D capability*FDI	0.056	(0.064)	0.081	(0.065)
s-Social Infrastructure	-0.113	(0.037)***	-0.101	(0.037)***
s-Social Infrastructure*Laborq	-0.051	(0.022)**	-0.028	(0.022)
s-Social Infrastructure*In-house R&D	0.074	(0.028)***	0.092	(0.029)***
s-Social Infrastructure*Export	0.095	(0.028)***	0.086	(0.028)***
s-Social Infrastructure*FDI	0.099	(0.047)**	0.106	(0.047)**
s-Phy. Infra.	-0.181	(0.076)**	-0.196	(0.077)*
s-Phy. Infra.*Laborq	-0.038	(0.025)	-0.012	(0.029)
s-Phy. Infra.*In-house R&D	-0.013	(0.045)	0.010	(0.046)
s-Phy. Infra.*Export	0.112	(0.033)***	0.106	(0.035)***
s-Phy. Infra.*FDI	-0.003	(0.051)	0.055	(0.054)
s-Export			0.057	(0.051)***
s-Export*Laborq			0.120	(0.036)***
s-Export*In-house R&D			0.073	(0.061)
s-Export*Export			-0.002	(0.001)***
s-Export*FDI			0.097	(0.076)
s-FDI	0.150	(0.040)***		
s-FDI*Laborq	-0.017	(0.030)		
s-FDI*In-house R&D	-0.027	(0.043)		
s-FDI*Export	-0.001	(0.001)		
s-FDI*FDI	-0.113	(0.059)*		
capitalw	0.717	(0.181)***	0.695	(0.179)***
Constant	4.087	(0.122)***	3.985	(0.124)***
Random part				
constant	-2.477	(0.532)***	-2.767	(0.554)***
laborq8	-21.284	-549.858	-13.641	-497.125
rd1	-1.476	(0.540)***	-1.468	(0.630)**
fdi2	-2.229	(0.307)***	-2.143	(0.319)***
export2	-0.465	(0.259)*	-0.479	(0.262)*
capitalw	-1.216	(0.184)***	-1.170	(0.188)***
e	0.199	(0.009)***	0.199	(0.009)***
# Sector	20		20	
# Firm	6219		6219	

Source: by the authors

Notes: Standard errors are in parentheses. *, **, and *** means 10, 5, and 1% level of significance, respectively (s-) represent sector-level variables as effective in terms of firm performance because they are not robust across models. Nevertheless, several interaction terms involving them are significant.

Innovation system: The interaction terms of human capital at the sector level with firm-level variables are all insignificant. However, R&D capability has a significant interaction with labor quality and exports. R&D capability increases the effect of LBE and labor quality on firm performance by 10 percent each.

International integration: The interaction of sector-level LBE follows the same direction as labor quality at the firm level. A high-export environment boosts the effect of labor quality on firm performance by 12 percent. However, the effect of FDI interaction was insignificant to firm performance.

Investment climate: The significant interaction effect of export and soft/physical infrastructure indicates that exporting firms tend to benefit from better IC conditions. Higher level of soft infrastructure tends to increase the effect of firm-level R&D, exports, and FDI on firm performance, while better physical infrastructure increases the positive effect of exports on firm performance.

Table 11 provides a summary of the results on the interaction terms between firm- and sector-level variables.

First, we find that although IC has no independent effect on firm productivity, it does have an impact when it interacts with firm-level activities such as exporting or FDI. These results reveal the channels

TABLE 11

RESULT SUMMARY OF FIRM- AND INDUSTRY-LEVEL INTERACTIONS

		s-IS		s-IC		s-II	
		Human capital	R&D capability	Social Infra.	Phy. Infra.	Iexport	Ifdi
	Direct effect	(+)***	(-)	(-)	(-)	(+)***	(+)***
f-IS	Laborq	(-)	(+)***	(-)	(-)	(+)***	(-)
	In-house R&D	(-)	(-)	(+)***	(-)	(+)	(-)
f-II	FDI	(+)	(+)	(+)***	(+)	(-)	(-)
	Export	(+)	(+)**	(+)***	(+)**	(+)	(-)

Source: by the authors

(s-) stand for sector-level

(f-) stand for firm-level

through which IC may affect firm productivity and imply that only those firms who are active tend to exploit the benefits from the surrounding environment. This finding implies that efforts to improve IC would not make sense, unless some firms tend to take advantage of such IC.

Second, regarding IS variables, while a low-class IS variable, such as sector-level human capital, has its own independent effect in the context of developing countries (as shown by its significance), a high-level IS variable, such as sector-level R&D, would have an effect only when it interacts with the firm-level capabilities of labor quality or exporting. This finding implies that any policy initiative to improve IS in developing countries should move first to human capital and then to R&D at the later stages or only after firm-level activities are developed sufficiently.

Third, we find that sector-level export orientation and FDI intensity have direct and significant effects on firm-level productivity, and that the interaction of sector-level exports with firm-level labor quality is positive and significant. The results thus confirm the importance of spillover from sector to firms, and such spillover seems to be high when firms have a high level of human capital.

The abovementioned results on interactions seem to be consistent with the reasoning that II is probably more robust than IS or IC, as sector-level II variables tend to have independent and significant effects on firm-level productivity. By contrast, sector-level IC variables have no independent effects but only make an impact when they interact with firm-level activities.

V. Summary and Conclusions

This study has attempted to investigate the importance of IC, II, and IS, measured at three different levels of firm, sector, and country. It also analyzed the interaction effects among them. In general, we find some pieces of evidence showing that firm-level variables tend to be more robust than higher-level variables, such as sector- or country levels, and II is more robust or important than IC or IS. The evidence includes the results showing that none of the country-level variables are significant, except for human capital variables, those showing the significance of sector-level II variables, and those showing the insignificance of both sector-level IC variables and sector-level R&D variables. We have also obtained the results showing that more of sector-level IC and IS variables become significant only in the interaction with firm-level variables.

Certainly, we should be careful not to attach extremely strong statements to these results, because they might depend on which proxies are adopted to represent IC, II, or IC and also because the number of countries in the sample cannot be considered sufficiently large. Despite this limitation, some conclusions can be made on the bases of more robust findings. Overall, the results of these proxies indicate the importance of firm-level capabilities, which can be enhanced by II (*e.g.*, firm-level LBE and FDI arrangements), IS (*e.g.*, firm-level education and training), and the spillover from sector-level II and human capital. These results reveal the channels through which IC may affect firm productivity. IC has no independent effect on firm productivity but works when it interacts with firm-level capabilities and activities. This finding implies that efforts to improve IC would not make sense, unless some firms are prepared to take advantage of better IC. In other words, the things that matter or bind more critically in developing countries are firm-level capabilities and learning in production, which developing countries need to enhance by arranging access to foreign knowledge through FDI or export. Only after this arrangement and learning would allow for the next step to seek higher-level capabilities, namely, innovation, by enhancing the IS at the firm, sector, and country levels, and thus promote better assimilation, diffusion, and creation of knowledge. This sequence of upgrading from production to innovation is consistent with the argument of GVC literature on upgrading in value chains through participation in GVC (UNCTAD, 2013: Lee *et al.*, 2018). It also agrees with the importance of correcting capability failure first and then moving to correct market failure and then system failure (Lee, 2013a).

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Appendix Tables:

TABLE 1
DESCRIPTIVE STATISTICS

	Variable	Obs	Mean	Std. Dev.	Min	Max
Firm level	lny	6523	4.876	3.375	-11.795	16.271
	Laborq	6260	0.000	1.022	-1.038	46.209
	In-house R&D	6523	0.316	0.465	0.000	1.000
	FDI	6523	0.098	0.297	0.000	1.000
	export	6479	20.052	35.817	0.000	100.000
Country level	Human capital	21	0.000	1.357	-1.695	3.111
	R&D capability	21	0.000	1.372	-3.000	1.737
	Physical infra.	21	0.000	1.163	-2.570	2.032
	Soft infra.	21	0.000	1.254	-2.277	3.231
	export	21	20.033	16.445	7.190	61.647
	FDI	21	0.098	0.071	0.000	0.333
Sector level	Human capital	20	0.000	1.148	-3.232	2.869
	R&D capability	20	0.000	1.000	-1.441	3.124
	Physical infra.	20	0.000	1.342	-2.783	7.087
	Soft infra.	20	0.000	1.155	-2.928	1.956
	export	20	0.338	0.212	0.000	1.000
	FDI	20	8.150	8.740	0.000	100.000

Source: by the authors

TABLE 2
KMO OVERALL TEST

Firm level	Human capital	0.55
Sector level	Human capital	0.51
	R&D capability	0.68
	Phys. Infra	0.5
	Soft Infra	0.52
Country level	Human capital	0.5
	R&D capability	0.6
	Phys. Infra	0.51
	Soft Infra	0.62

Source: by the authors

TABLE 3
CORRELATION MATRIX

		Firm level						Country level						Sector level					
		lny	Laborq	In-house R&D	FDI	export	capitalw	Human capital	R&D capability	Physical infra.	Soft infra.	export	FDI	Human capital	R&D capability	Physical infra.	Soft infra.	export	FDI
Firm level	lny	1																	
	Laborq	0.131	1																
	In-house R&D	0.145	-0.008	1															
	FDI	0.030	-0.001	0.012	1														
	export	-0.035	-0.001	-0.086	0.171	1													
	capitalw	0.252	0.057	0.040	-0.014	-0.032	1												
Country level	Human capital	0.592	0.133	0.053	-0.110	0.107	0.138	1											
	R&D capability	0.073	-0.217	0.304	-0.005	-0.038	-0.014	0.067	1										
	Physical infra.	0.080	0.157	0.056	-0.067	-0.342	0.046	-0.205	-0.398	1									
	Soft infra.	-0.173	-0.208	0.136	-0.047	-0.160	-0.057	-0.244	0.594	-0.103	1								
	export	-0.097	-0.028	-0.223	0.106	0.460	-0.027	0.227	-0.081	-0.743	-0.344	1							
	FDI	-0.149	-0.103	-0.136	0.240	0.205	-0.055	-0.460	-0.021	-0.280	-0.196	0.444	1						
Sector level	Human capital	-0.424	-0.157	0.087	0.088	-0.104	-0.079	-0.728	0.250	0.150	0.198	-0.246	0.235	1					
	R&D capability	0.236	-0.076	0.472	-0.046	-0.230	0.030	0.110	0.650	0.117	0.293	-0.470	-0.283	0.183	1				
	Physical infra.	-0.075	-0.149	0.153	-0.038	-0.172	-0.037	-0.088	0.377	-0.047	0.754	-0.354	-0.254	0.030	0.327	1			
	Soft infra.	0.062	0.143	0.060	-0.069	-0.327	0.048	-0.206	-0.391	0.971	-0.102	-0.718	-0.268	0.166	0.127	-0.040	1		
	export	-0.122	-0.089	-0.014	0.171	0.440	-0.064	-0.128	0.150	-0.352	-0.123	0.379	0.388	0.217	-0.023	-0.188	-0.351	1	
	FDI	-0.081	-0.059	-0.052	0.330	0.198	-0.051	-0.326	0.008	-0.180	-0.113	0.296	0.700	0.254	-0.105	-0.084	-0.184	0.500	1

Source: by the authors

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