Hing Vutha; Shandre Mugan Thangavelu; Kong, Ratha

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TECHNOLOGY, INNOVATION, AND FIRM COMPETITIVENESS: FIRM LEVEL ANALYSIS IN CAMBODIA

Vutha Hing, Shandre Thangavelu,
and Ratha Kong

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Vutha Hing is a PhD candidate at the Institute for International Trade, University of Adelaide. Shandre Thangavelu is a professor at the Jeffrey Cheah Institute for Southeast Asia, Sunway University and a professor at the Institute for International Trade, University of Adelaide. Ratha Kong is a PhD student at the Institute for International Trade, University of Adelaide.

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Please contact the authors for information about this paper.

Email: shandre.thangavelu@adelaide.edu.au

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

The paper examines the innovation and competitiveness of firms, especially with regard to the channels of technology transfer and the nature of innovation activities that influence firm performance in the Cambodian economy. Despite the growing importance of innovation, there has been no empirical analysis of the factors affecting technological and innovative development and the impact that these factors have on firms' productivity in Cambodia. We use the World Bank Enterprise Survey (WBES) for Cambodian enterprises for our empirical implementation. The results of the research indicate that overseas linkages that include both upstream and downstream activities could affect productivity growth at both firm and industry levels. We also find that technology and innovation have a positive impact on the productivity of firms in Cambodia.

Keywords: technology, innovation, productivity, human capital, export and import

JEL Classification: D240

Contents

1. INTRODUCTION

The National Innovation System (NIS) is critical for the development of key innovation strategies and economic fundamentals for sustainable and inclusive growth. The NIS builds a coherent and integrated framework to create sustainable and inclusive growth. The NIS framework is critical in terms of identifying the linkages between businesses and public policies, developing key fundamentals of competitiveness of domestic firms, identifying the linkages between domestic firms and multinational firms, developing the vital human capital to fully participate in the innovative and economic activities in an open economic system, creating tangible and intangible knowledge capital in the domestic economy, and creating forward-looking policies and institutions to support the creative and knowledge-based economic development in the economy (Asian Development Bank 2014). The NIS framework is also important to manage the uneven impact of economic development from economic liberalization, and it will have a direct impact on the inclusive development of domestic firms, the management of rural and urban sector inequalities, and will directly address the digital divide and inequalities in the domestic economy. The NIS framework recognizes the importance of government policies to coordinate and manage the key innovation framework in the domestic economy.

It is clear that technology and innovation are key for domestic industries to be competitive and to create sustainable development in the domestic economy in the long run. Their significance and impact on long-term economic development and economic growth is widely recognized in the literature (i.e., Grossman and Helpman 1991; Romer 1994). Technological progress can also have positive spillovers in developing countries to boost technological capacity and enhance productivity, which serve as crucial vehicles to catch up to developed countries (Coe, Helpman, and Hoffmaister 1997; Fagerberg, Srholec, and Knell 2007; Grossman and Helpman 1991). The growth pattern in East Asia provides strong evidence of the crucial impact of technology and innovation on the competitiveness of the region's economies and firms. Technological progress is in large part driven by technological transfer obtained from channels such as trade, foreign direct investment (FDI), reverse engineering, technology licensing, original equipment manufacturers, and labor mobility.

Although there are several studies focused on identifying the technology, innovation, and growth of economies at the aggregate level as well as on the micro evidence of the factors that determine firms' competitiveness in developed countries, there are few studies that focus on the innovation and competitiveness of firms in developing countries, especially with regard to the channels of technology transfer and the natures of innovation activities that influence firm performance. The relationship between technology, innovation, and firm competitiveness is given in the firm heterogeneity theory, which acknowledges the significant differences in human capital, production and technological capacity, infrastructure and connectivity, and exposure to international markets across firms in the domestic economy. It is clear that such heterogeneity can affect a firm's and industry's competitiveness. There is anecdotal micro evidence based on firm data analysis that explains the nexus between technology and firm performance. For example, Branstetter and Chen (2006) relied on Taipei,China industrial census data to analyze the impact of technology transfer and research and development (R&D) on productivity growth. Their results suggested that R&D expenditure and purchases of foreign technology have a positive impact on domestic productivity growth. Similarly, Chudnovsky, López, and Pupato (2006) examined the innovation and productivity of manufacturing firms in Argentina and found that in-house R&D and technology acquisition expenditures enhance the probability of

innovation, which, in turn, drives higher productivity levels than that of non-innovators. It is also interesting to observe the studies that capture the effects of different technology channels and the nature of innovation activities on firm performance. Firm-level analysis in the People's Republic of China (PRC) found evidence that the import of more capital goods and the utilization of foreign technologies tends to help firms improve their productivity (Bilgin, Marco Lau, and Karabulut 2012). In Brazil, firms are increasingly adopting innovation strategy via product and process innovation, which is determined by technology acquisition, financial resources, workforce skills, and management quality and is an important driver of firm growth (Goedhuys and Veugelers 2012). The backward linkages created by the Japanese multinationals through local backward linkages and local procurement in the host country were carefully examined by Kiyota et al. (2008).

Despite growing research, there is still a lack of key studies on the effects of technology and innovation on the performance of firms in less developed ASEAN countries such as Cambodia. The impact of multinational activities on the productivity performance of domestic firms depends on the domestic absorptive capacity of the firms and on the strength of the backward and forward linkages established in the domestic economy (Thangavelu, Urata, and Ambaw 2021; Görg and Greenaway 2004; Girma, Görg, and Pisu 2008). Using the firm-level analysis in the PRC, Du et al. (2012) showed a significant positive productivity spillover effect through backward and forward linkages, but not through horizontal linkages. Technological spillovers and transfers also depend on the domestic absorptive capacity, such as infrastructure, special economic zones, and human capital in the domestic economy (Thangavelu and Narjoko 2014). We can also observe transfer technology from foreign-owned firms to domestic firms through labor turnover (Kiyota and Urata, 2008).

The technological and innovative capacities of the Cambodian economy are quite low as the technology and innovation ecosystem are in the early stages of development. But the Cambodian economy is accelerating the development of infrastructure and upgrading the special economic zones to attract and retain quality foreign direct investment in the Cambodian economy. However, there is no empirical analysis on the factors affecting Cambodia's technological and innovative development and their impact on firms' productivity. This paper aims to fulfil this knowledge gap by empirically assessing the impacts of technology, innovation, and domestic absorptive capacity in human capital on firm performance in Cambodia. Specifically, it seeks to address two main questions:

a. What is the extent of technology and innovation adoption among Cambodia's enterprises?

b. What is the impact of technology, innovation, and domestic absorptive capacities, especially human capital, on firm performance?

To answer these questions, we adopt firm heterogeneity theory to guide our empirical analysis. The framework takes the firm as the central unit of analysis and uses the World Bank Enterprise Survey (WBES) for Cambodian enterprises for our empirical implementation. WBES employs a standardized questionnaire across different countries to record firm information and behavior on broad issues of business operation and environment.

2. LITERATURE REVIEW

Literature on technology, innovation, and firm performance has notably grown, reflecting the importance of technological progress in corporate strategy and competitiveness. Conceptually, the technological and innovative capacities of a firm are important sources of competitive advantage that will support firm performance in the market. This section reviews empirical literature on factors that affect firm productivity levels with particular emphasis on the role of innovation and technology in productivity improvement.

The empirical research on technology, innovation, and productivity is diverse in thematic focus, approach, and measurement. The first strand of literature adopts the Cobb–Douglas production function to directly derive the impact of innovation and technology on productivity. Specifically, innovation and technology are incorporated into the production function along with labor, capital, and material that have coefficients that determine productivity impact. Among this literature is Branstetter and Chen's (2006) study of firms in Taipei,China. In this study, innovation and technology were proxied by R&D spending and purchases of foreign technology, respectively. They were then included in the production function for productivity impact estimation using a fixed-effect panel estimator. The authors found evidence that supports the conclusion that both R&D spending and purchases of foreign technology have positively contributed to Taipei,China productivity growth.

Tsai (2004) also conducted an empirical investigation using Taipei,China firm data. This study defines technological capability as the assimilation and application of the technological knowledge from R&D activities, and it found evidence that technological capability positively contributed to productivity growth in the electronic industry of Taipei,China. Similarly, Hu, Jefferson, and Jinchang (2005) estimated the production function based on PRC manufacturing firms with R&D expenditure and domestic and foreign technology transfer as inputs. They basically found that R&D and foreign technology transfer have positive effects on firm productivity. They also found evidence that the effects of both domestic and foreign technology transfer on firm productivity are largely conditional on R&D expenditure, which indicates the critical role of in-house R&D capabilities as an important channel for absorbing externally-acquired technologies. Despite being able to capture the direct effect of innovation and technology on productivity, this sort of study fails to account for other important factors, including firm age, ownership structure and import and export that could possibly affect firm productivity.

The second strand of literature has estimated the impact of innovation on productivity based on the so-called Crépon-Duguet-Mairesse (CDM) model. Pioneered by Crépon, Duguet, and Mairessec (1998), the model comprises three stages of estimation. The first stage estimates the determinants of the probability to conduct R&D and the intensity of R&D based on the innovation equation. The second stage examines the determinants of the probability to be innovative, and the third stage determines the productivity effect of innovation outputs and other explanatory variables, including physical and capital intensity. Using French manufacturing firm data, Crépon, Duguet, and Mairessec (1998) found that firm size, market share and diversification, technology push, and research effort positively correlate with propensity to conduct R&D. They also found firm productivity positively correlates with higher innovation output. Goedhuys and Veugelers (2012b) followed the CDM model and used firm-level data in Brazil to identify the innovation strategies of firms and their effects on innovation outcomes and firm growth. The study confirmed that factors such as technology acquisition, human capital, access to finance, and international linkages are important

for stimulating innovative and growth performance. Similar empirical investigations have been conducted by Lööf and Heshmati (2002) for Swedish manufacturing firms and Mishra et al. (2021) for Indian enterprises. For Swedish firms, a lack of appropriate investment sources for innovative activities was found to have a negative impact on productivity. In contrast, neither product nor process innovation contributed significantly to the productivity of Indian firms. However, product and process innovation positively determined innovation outputs, which is a significant contributor to firm productivity.

The third strand of productivity literature strictly follows an empirical framework that estimates total factor productivity from the Cobb-Douglas production function and then regresses the derived productivity with the firm characteristic variables of interest. For example, Urata and Baek (2021) adopted the two-stage empirical approach to examine the impact of local firms' participation in global value chains (GVCs) on productivity. Total factor productivity was calculated using different estimation methods, including the system GMM econometric framework by Wooldridge (2009) and the semi-parametric approach proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003). The main conclusions from this study were that two-way trade via both the importation of intermediate goods and the exportation of output helps firms improve their productivity; and that the scale of economy and technological development proxied by quality certification are important factors in improving productivity. Şeker (2012) assessed the effect of importing, exporting, and innovating on firm performance using the WBES of 43 developing countries. It was found that technological innovation is positively and significantly correlated with firm growth. Specifically, firms that introduced new products over the past three years were 18% more productive than the firms that did not introduce a new product.

Jamal (2018) examined the determinants of productivity among manufacturing firms in Pakistan using firm level data gathered in the WBES. Measures of innovation and technology included an ISO certificate, a technology license from a foreign enterprise, information and communication technology (ICT), and product and process innovation. The study concluded that while a technology license from foreign enterprises does not result in a productivity increase, technology obtained through foreign ownership, ICT, and process innovation positively affected the productivity level. Belderbos, Van Roy, and Duvivier (2013) examined the impact of international and domestic technology transfers on firm productivity performance in Belgium. Total expenditure on technology, R&D expenditure, and technology transfer were included in the estimation to capture the effect of productivity on innovation and technology. The study found evidence that R&D and technology acquisition expenditures have a positive effect on productivity growth. Specifically, the gain in productivity growth is 10 percentage points for international technology transfer.

It is important to note that empirical research on innovation, technology, and productivity to date has tended to look at firm-level evidence from multiple countries and from more advanced economies. Thus, there is a scarcity of studies on the extent to which productivity levels differ between firms with different innovation and technology capabilities in the least developed countries (LDCs), including Cambodia. This paper, therefore, aims to remedy this gap by assessing the productivity effect of innovation and technology using the WBES in Cambodia in 2013 and 2016.

3. OVERVIEW OF SCIENCE, TECHNOLOGY, AND INNOVATION (STI) IN CAMBODIA

3.1 National STI Policy

Cambodia's STI is still under development, its innovation performance lags behind most developing countries, and its STI institutional and policy framework is still at the nascent stage. The country was ranked 109 out of 132 countries in the 2021 Global Innovation Index. It scored particularly low in education, R&D, knowledge-intensive employment, knowledge absorption, and knowledge creation. Cambodia adopted its first STI policy 2020–2030 in 2019 and replaced the former Ministry of Industry and Handicraft with the Ministry of Industry, Science, Technology, and Innovation (MISTI) as the institution to lead and coordinate STI initiatives and support key stakeholders (UNESCAP 2021).

The Cambodian National STI policy envisions the building of national capacities in STI and the improvement of the STI ecosystem for sustainable and inclusive development. The policy focuses on five scientific and technological domains: agricultural yield increase, produce diversification and agri-processing; modern production and engineering; health and biomedical; material science and engineering; and services and digital economy, including artificial intelligence and space and spatial technology. The policy also highlights major challenges in promoting STI, which include an unbalanced industrial ecosystem, insufficient human resources, and knowledge generation with respect to the governance of STI and problems with its coordination. The STI Roadmap was put in place to achieve the stated objectives and address the challenges. It has strategies focused on five main pillars.

- Pillar one aims to ***enhance the governance of the STI system*** by consolidating the mandate of MISTI; strengthening awareness and capacities of the government to implement the STI policy; and monitoring and evaluating advances made in the promotion of STI.
- Pillar two focuses on ***building human capital in STI***. Action plans include enhancing the scientific culture of society; enhancing the technology readiness of youth; increasing the attractiveness of the Science, Technology, Engineering and Mathematics (STEM) curricula and the number of graduates; and strengthening the quality of teaching and connection with the private sector.
- Pillar three emphasizes ***strengthening research capacity and quality***. Key measures include supporting high quality research and development activities; developing a national research agenda with the academic community and in close collaboration with the private sector; providing funding to support excellence in science; supporting the internationalization of research; and encouraging collaboration with the private sector.
- Pillar four is to ***increase collaboration and linkages between different actors***. Key policy measures include supporting innovation in small and medium-sized enterprises (SMEs) and enhancing their absorptive capacities; promoting incubation and acceleration facilities to support start-up creation; and piloting technology and innovation parks and clusters to foster collaborations and technology/knowledge between large firms, SMEs, and higher education/research institutions.

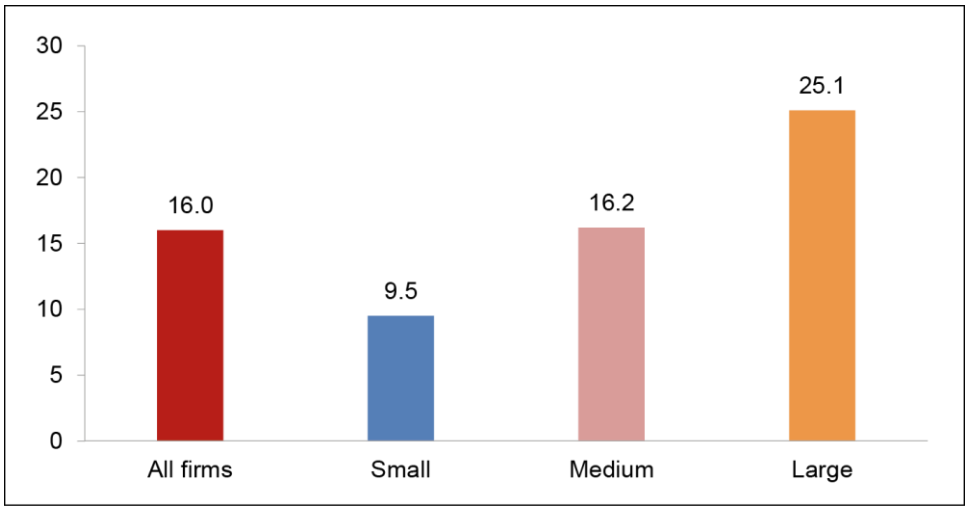
- Pillar five aims to ***foster an enabling environment for innovation*** through supporting innovation capabilities and increasing the absorptive capacities of firms; supporting technology transfer; and fostering domestic technologies. It also requires an increase in access to finance for innovation activities, including through leveraging investments from the private sector, attracting funding from donors, and incentivizing foreign direct investment that supports the building of domestic technological capabilities.

Despite its low ranking in innovation performance, Cambodia has made notable progress in its STI development trajectory. One of the most important milestones is that STI has been firmly acknowledged as a driving force to achieve the country's Vision 2050 of becoming an upper-middle income country by 2030 and a high-income economy by 2050 and to achieve national goals for sustainable development. Furthermore, Cambodia has witnessed rapid progress in its technology start-up ecosystem and growing support for innovation from the private sector (UNESCAP 2021). Over the past 5 years, there have been over 300 active technology start-ups that are currently operating at various stages of development. There is an increase in co-working spaces, incubators, local angel investors, private equity, and venture capital funds in the market. The growing participation of education institutions also plays a part in Cambodia's improved STI ecosystem. Some universities are establishing their own incubation and start-up centers to contribute to the promotion of entrepreneurship and innovation, while others, including those that provide technical and vocational training, sharpen their training programs around STI.

3.2 Innovation and Technology at the Firm Level

This section highlights the extent to which Cambodia's enterprises engage in innovation and technology activities. The statistics are extracted from the WBES of Cambodian enterprises in 2013 and 2016. Figure 1 indicates that 16% of enterprises obtained technology licenses for foreign technology.

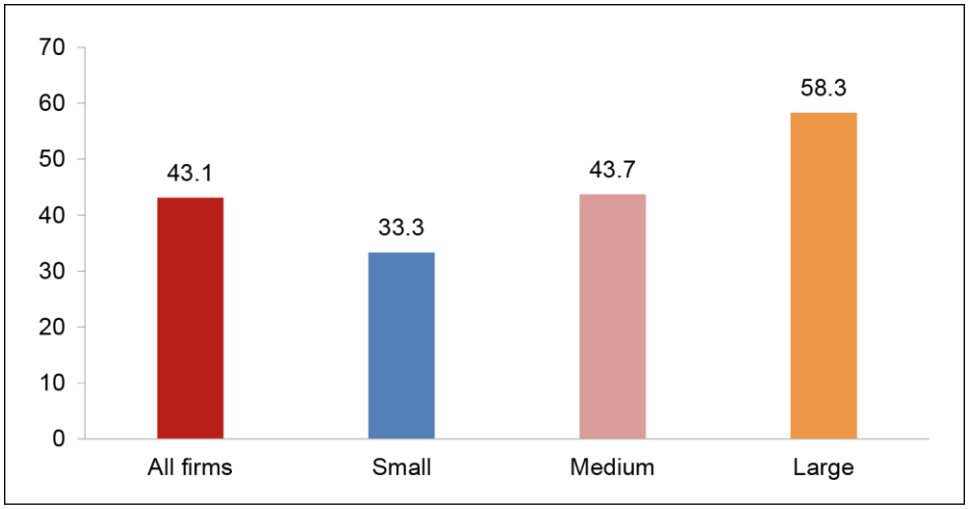
Figure 1: Share of Cambodia's Firms that Obtained a Technology License
(%)



Source: Author's calculation based on the WBES of Cambodia in 2013 and 2016.

Interestingly, we observe that a greater proportion of firms are undertaking innovative measures in the production of goods and services. Based on Figure 2, about 43% of Cambodia's firms are introducing new or significantly improved methods for the manufacture of products or the offer of services. Method and process innovation are also found to be high among small firms with the ratio at 33.3%.

Figure 2: Share of Cambodia's Firms Introducing Process Innovation



Source: Author's calculation based on the WBES of Cambodia in 2013 and 2016.

4. EMPIRICAL STRATEGY AND DATA SOURCE

4.1 Empirical Strategy

In this paper, we measured firm performance by productivity level and adopted a two-stage approach to estimate the effect of innovation and technology on productivity. In the first stage, we estimated firm-level total factor productivity (TFP) based on the Cobb-Douglas production function. The estimation of production function applied the semi-parametric approach developed by Levinsohn and Petrin (2003). In the second stage, we regressed the derived productivity with innovation, technology, and other firm attribute variables.

4.1.1 Estimation of Productivity

Let us assume the production of firm *i* at time *t* takes the form of the Cobb-Douglas production function as follows:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} M_{it}^{\beta_m}, \quad (1)$$

where Y_{it} represents physical output; A_{it} is efficiency level; and $K_{it}, L_{it}, and\ M_{it}$ are capital, labor, and material, respectively. Taking natural logs of equation (1) and denoting lower case for log form of all variables, we obtain:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \varepsilon_{it} \quad (2)$$

The estimation of equation (2) using Ordinary Least Square (OLS) is likely to be biased due to endogeneity between regressors and error terms (Arnold 2005; Levinsohn and Petrin 2003; Van Beveren 2012). In this case, the traditional methods used by some researchers to deal with the endogeneity issue, including fixed effect and instrument variable, still cannot generate consistent estimates because the assumption of strict exogeneity of inputs conditional on firm heterogeneity is unrealistic (Van Beveren 2012; Wooldridge 2009). Olley and Pakes (1996) corrected for this endogeneity problem by developing a semi-parametric technique (known as the OP method) that incorporates firm investment decisions to control unobserved productivity shocks. They proved that the OP method can solve both simultaneity between input choice and productivity shocks. One major weakness of the OP method is a truncation issue caused by a significant number of zero value investments (Levinsohn and Petrin 2003). Built on the work of Olley and Pakes (1996), Levinsohn and Petrin (2003) used intermediate inputs like material or electricity to proxy for the unobservable productivity term to correct the simultaneity between input choices and productivity shocks. Similar to OP, Levinsohn and Petrin's (2003) LP method satisfactorily addresses the endogeneity problem and generates consistent estimates for the production function estimation. From a data-driven perspective, LP is more efficient than the OP estimator in the sense that a majority of firm-level datasets report non-zero values for intermediate inputs (Levinsohn and Petrin 2003; Vial 2006).

Based on consistency and efficiency, this study adopted the LP method to estimate production function. We also followed Francis et al. (2020) in measuring key variables of the production function. Specifically, output y_{it} was proxied by annual sales (revenue-based approach); labor (l_{it}) was proxied by total number of workers; and capital (k_{it}) was measured by values of purchased machinery, vehicles, and equipment. As in Vial (2006), we opted for electricity, measured by the annual cost of electricity, as the proxy variable to control unobserved productivity. All variables are in the log form. With the production input coefficients obtained from the above estimation, we obtained the log of TFP of firm i at time t from the following expression:

$$tfp_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it} \quad (3)$$

4.1.2 Econometric Specification for Technology, Innovation, and Productivity

In the second stage, we adopted the firm heterogeneity model to estimate the effects of technology and innovation on productivity. The model stipulates that a firm's performance is a function of technology, innovation capacities, and other firm attributes. We estimated the causal relationship between technology, innovation and productivity based on the following econometric specification:

$$ln\_tfp_{ist} = \alpha_0 + \beta_1 inn_{ist} + \beta_2 for\_tech_{ist} + \beta_3 ICT_{ist} + \beta_4 X_{ist} + d_t + d_s + \varepsilon_{isrt} \quad (4)$$

where subscript *i* denotes firm, *s* is sector, and *t* is time. Variable *tfp* is total factor productivity derived from the estimation of equation (3), while variables *inn* and *tech* refer to innovation and technology, respectively. Similar to Goedhuys and Veugelers (2012a), we captured innovation activities of firms by their process innovation. The innovation variable (*inn*) takes value 1 if a firm successfully introduced new technology that has substantially changed the way the main product is produced. For technology, we followed Şeker (2012) and measured technological capacity with two variables. The first proxy relates to foreign technology adoption (*for_tech*), where the variable takes value 1 if a firm uses technology licensed from a foreign-owned company. The second

proxy relates to ICT infrastructure, denoted as *ICT* in Equation (4) We assigned value 1 for this variable if a firm uses email to interact with clients and suppliers and 0 otherwise. We hypothesized that innovation and technology variables will have a positive and significant impact on firm productivity.

In our model, X_{ist} is a vector of other firm characteristics that may affect productivity. As in most productivity studies, we controlled for a number of firm characteristics, including age, ownership structure, access to finance, human capital, import of materials, and export status. The firm age *(age_{ist})* in our model refers to number of years in operation. The foreign ownership *(for_own_{ist})* variable takes value 1 if the establishment is foreign owned and 0 otherwise. We defined foreign-owned firms as those that have 10% or more of their capital stake owned by foreign individuals, companies, or organizations. We defined a firm with better access to finance (acc_fin_{ist}) as those that have a credit line/loan from a financial institution. Like most firm heterogeneity empirics, we anticipated that size, age, foreign ownership, and access to finance would have a significant and positive relationship with productivity. We also controlled for firm orientation to foreign market in the productivity estimation.

We used two separate measures to capture various aspects of human capital in enterprises. First, we used skill intensity *($skill_{ist}$)*, which was measured by the share of skilled production workers to total employees. The second variable in our model reflects the firms' training program for employees ($training_{ist}$). It takes the value 1 if a firm provides formal training to its employees and 0 otherwise. Since the quality and ability of workers within an enterprise is the fundamental resource for success, we hypothesized that firms with a higher quality of human capital are more productive.

Like several productivity studies, we captured a firm's import and export status in the productivity estimation. The import variable *($import_{ist}$)* takes 1 if a firm imports raw material from abroad and 0 otherwise. Similarly, export *($export_{ist}$)* equals 1 if a firm exports its main product to a foreign market and 0 otherwise. We anticipated that exposure to international markets both in terms of using foreign intermediate inputs and links with foreign consumers would have positive spillover effects on productivity level. To control for the unobserved shocks that may affect productivity over time and across different sectors, our econometric specification also included year-fixed effect d_t and sector-fixed effect d_s.

The final estimation equation is given as:

$$\begin{aligned} ln\_tfp_{ist} = {} & \alpha_0 + \beta_1 inn_{ist} + \beta_2 for\_tech_{ist} + \beta_3 ICT_{ist} + \beta_4 \ln age_{ist} \\ & + \beta_5 for\_own_{ist} + \beta_6 acc\_fin_{ist} + \beta_7 skill_{ist} \\ & + \beta_8 training_{ist} + \beta_9 import_{ist} + \beta_{10} export_{ist} + d_t \\ & + d_s + \varepsilon_{ist} \end{aligned} \quad (5)$$

4.2 Data Sources

In the absence of a comprehensive enterprise census in Cambodia, we used the WBES as the primary source of data. The survey of enterprises in Cambodia was conducted in 2013 and 2016 with a total sample of 845 firms. However, our panel data was unbalanced as there are enterprises in our panel that only participated in either the 2013 or 2016 survey. Summary statistics are presented in Table 1.

Table 1: Summary Statistics

Variable	Observation	Mean	Std. Dev.
Total factor productivity (in thousand USD)	460	159,999.3	1,116,298
Age	460	12.94348	6.403725
Foreign ownership (%)	460	0.308696	0.462458
Access to finance (%)	460	0.236957	0.425678
Foreign technology (%)	460	0.16087	0.367811
ICT infrastructure (%)	460	0.634783	0.482015
Process innovation (%)	460	0.513044	0.500374
Skill intensity (%)	460	32.21162	36.22842
Training (%)	460	0.41087	0.492527
Import of intermediate inputs (%)	460	0.304348	0.460632
Export firms (%)	460	0.180435	0.384968

The data also captures both manufacturing and service firms. The data for manufacturing is comprised of 20 predefined sub-sectors, including food, tobacco, textiles, garments, leather, wood, paper, publishing and printing, refined petroleum products, chemicals, plastics and rubber, non-metallic mineral products, basic metals, fabricated metal products, machinery and equipment, electronics, precision instruments, transport machines, furniture, and recycling. The data for service industries includes the sub-sectors of retail, wholesale, information and technology, hotel and restaurant, services for motor vehicles, construction, and transport.

4.3 Estimation Method

We estimated equation (5) using ordinary least squared (OLS) as the baseline estimation.

To account for variations across different industries and periods, we controlled sector and time-fixed effects in our estimation. We introduced two robustness checks to show that our baseline results are robust. First, we re-estimated equation (5) with an alternative measure of total factor productivity using the log of annual sales per worker. Second, we adopted an instrument variable (IV) estimator as an alternative strategy to address endogeneity concerns. We followed the strategy used by Li, Jin, and Ding (2019) by generating two aggregate variables, namely an average value of innovation and an average value of foreign technology adoption at the firm level in each region as instrument variables. The instruments were selected based on the thought that an average innovation and foreign technology value by region are highly correlated with firm innovation and foreign technology adoption, but they are weakly correlated with firm productivity. The IV regression is estimated using the Two-Stage Least Square (2SLS) method.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1 Baseline Results

The results by fixed effect are given in Table 2. The estimation includes year fixed effects to control for any unobserved time-varying shocks that affect the productivity level of firms. It also accounts for unobserved factors that might affect firm productivity across different sectors by including industry fixed effects in our estimation. The table

reports the standard errors in parentheses. The results of the estimated coefficients are of the expected sign and statistically significant. The estimates are also generally stable across different specifications.

Table 2: Estimation Results for Innovation, Technology, and Productivity

	(1)	(2)
Variables	**OLS_FE**	**OLS_FE**
Age	0.228*	0.0528
	(0.122)	(0.157)
Foreign ownership	0.954***	0.538***
	(0.297)	(0.0460)
Access to finance	0.697***	0.429
	(0.0579)	(0.262)
Foreign technology	0.640***	0.353*
	(0.243)	(0.202)
ICT infrastructure	0.643**	0.384
	(0.254)	(0.284)
Process innovation	0.336***	0.257**
	(0.0369)	(0.128)
Skill intensity (share of skilled labor)	0.00345**	
	(0.00172)	
Skill intensity (average wage to total employees)		0.870***
		(0.0141)
Formal training	0.523***	0.275*
	(0.141)	(0.142)
Import of inputs	0.727***	
	(0.217)	
Share of imported input		0.00840***
		(0.00120)
Export status	0.923***	1.033***
	(0.128)	(0.0627)
Constant	1.011***	3.895***
	(0.332)	(0.329)
Observations	460	448
R-sq	0.8577	0.9253
Year-FE	Yes	Yes
Sector-FE	Yes	Yes

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Before discussing the effect of innovation and technology on productivity, we will discuss the results for other firm level characteristics. The coefficient of age variable is positive and significant, suggesting that firms with longer years of operation tend to have higher productivity. The result is similar to Jamal (2018) and Goedhuys and Veugelers (2012a), but contradictory to Ospina and Schiffbauer (2010). The foreign ownership coefficient is positive and statistically significant, which implies that foreign-owned firms are more productive than their domestic counterparts. The result is consistent with several prior studies, including Urata and Baek (2021), Görg, Hanley, and Strobl (2008), and Jamal (2018). The result supports the claim that foreign-owned firms have several advantages, including human and capital resources, technological

and production capabilities, and access to foreign networks, which contribute to higher productivity. Access to finance is also found to positively affect productivity levels. Specifically, firms that get loans from banks or financial institutions are more productive than those that do not have any access to bank loans.

The estimated coefficient for skill intensity and training is strongly positive, allowing us to argue that firms with higher levels of human capital are more productive. The importance of human capital in raising a firm's productivity is not uncommon in the empirical literature. For example, Crépon, Duguet, and Mairessec (1998), Pham (2015), and Pattnayak and Thangavelu (2014) revealed that having a higher skilled workforce increased the productivity of firms; while Jamal (2018) found that productivity improvement is strongly associated with the educational level of production workers.

The general conclusion could be disputed on the ground that several empirics measure skill intensity somewhat differently. We took this into consideration and included an alternative variable for skill in our estimation. We followed Thangavelu (2014) to measure skill intensity based on wages and salaries. We defined the skill intensity as the ratio of wages and salaries to total employees, which can be called the average wage of a firm. This proxy was used in Thangavelu (2014) to measure the quality of human capital under the assumption that firms with higher average labor costs per worker employ higher skilled labor. The estimation results using the alternative skill measure is given in Column 2 of Table 2. The signs and magnitudes of all variables are comparable to previous estimations with the coefficients of skill and training; in addition, foreign ownership, foreign technology, share of imported inputs, and export status are all positive and statistically significant. Therefore, we can conclude that human capital is an important asset that can help firms raise their productivity.

As anticipated, coefficients of intermediate input imports and export are strongly positive, indicating the importance of foreign connections in increasing the efficiency and productivity of firms. More precisely, exporting firms or firms sourcing intermediate inputs from abroad are more productive. This result provides a useful comparison of productivity levels among firms using imported inputs and firms that do not. However, the results do not provide clear insights on the extent to which imported input affects productivity levels. We explored this issue and again re-estimated equation (5) by replacing import dummy with share of imported inputs. As shown in Column 2 of Table 2, the result indicates that import intensity has a positive effect on productivity and is statistically significant.

Overall, our results are consistent with several similar works, including Baldwin and Yan (2014); Crépon, Duguet, and Mairessec (1998); Criscuolo and Timmis (2017); Pattnayak and Thangavelu (2014); Urata and Baek (2021); and Wagner (2012). These studies found overseas linkages that included both upstream and downstream activities that could affect the productivity growth at both firm and industry levels. More precisely, firms can improve productivity when they import intermediate goods and/or directly export output. One possible explanation to the positive import and export-productivity nexus is the spillover effect from the adoption of foreign technology and a high-quality standard of production and services to meet the foreign market requirement. There is also a growing discussion about the importance of technology embodied in the imports. Amiti and Konings (2007), for example, argued that productivity gain is larger for importing firms than non-importing firms. The positive relationship between import, export, and the productivity nexus offers additional evidence that explains the prevailing global trend of firms striving to join international trade, including global value chains and production networks.

Lastly, our empirical results suggest that innovation and technology are positively associated with productivity. Firms that obtain a technology license from a foreign company and those that use email to interact with their business partners are more productive than their counterparts. This finding implies that technological orientation and ICT infrastructure are the important drivers of productivity improvement. We also found that firms that introduce any new or significantly improved production processes tend to have higher productivity levels. The findings are consistent with several existing studies, such as Belderbos, Van Roy, and Duvivier (2013); Goedhuys and Veugelers (2012a); Jamal (2018); Şeker (2012).

5.2 Differentiating the Impact of Technology and Innovation

This section further explores the extent to which the impact of technology and innovation on productivity differs across firm ownership structures. To obtain the differentiated impacts, we estimated equation (5) separately for manufacturing firms and service firms as well as for domestic and foreign owned firms. The estimation results are reported in Table 3. There are a couple of notable variations in results across the two sectors. First, the technology variable tends to have greater importance for service firms than manufacturing firms in terms of productivity enhancement. This is reflected by the larger positive coefficient of foreign technology in the estimation for service firms compared to manufacturing firms. ICT infrastructure has a positive and statistically significant effect on productivity for service firms but is statistically insignificant for manufacturing firms. Based the on the sectoral disaggregation, the results also suggest that process innovation has an insignificant impact on productivity for both sectors. Second, while it is found that access to finance, foreign ownership, and imported materials have significant effects on productivity for manufacturing firms, the results do not hold for service firms. Like estimation for all sectors, skill and export status are found to be crucial for productivity improvement in both sectors. However, we observe that the magnitudes of the impact are greater for service firms compared to manufacturing firms.

We also observe certain variations in the impacts of technology and innovation on productivity among domestic and foreign firms. For domestic firms, foreign technology is far more important than ICT infrastructure and process innovation. One possible reason for the results is that technological capacity among domestic firms is relatively low, and thus, the purchase and use of foreign technology is more important. On the other hand, foreign firms already own technology and do not need to purchase a license to use foreign technology. The casual relationship tends to be the opposite for foreign firms in which innovation significantly drives productivity but technology does not. Access to finance, skill intensity, and export status tend to have greater impacts on productivity for domestic firms than foreign firms. Access to finance would be much more important for domestic firms than foreign firms because domestic firms are more constrained in financing than foreign firms that can rely on their parent companies for financing. For imported materials, it is found otherwise if the estimated coefficient is smaller for domestic firms.

Table 3: The Impact of Technology and Innovation on Productivity by Sector and Ownership Structure

Variables	(1) Manufacturing	(2) Services	(3) Domestic Firm	(4) Foreign-owned Firm
Age	0.0899	–0.209	–0.0103	0.167
	(0.352)	(0.142)	(0.0435)	(0.281)
Foreign ownership	0.855***	0.0978		
	(0.0674)	(0.441)		
Access to finance	0.755***	–0.157	0.497*	0.105*
	(0.113)	(0.169)	(0.272)	(0.0583)
Foreign technology	0.400***	0.848***	0.573***	0.0156
	(0.119)	(0.272)	(0.102)	(0.455)
ICT infrastructure	0.333	0.342*	0.396	0.179
	(0.593)	(0.174)	(0.308)	(0.115)
Process innovation	0.00169	0.397	0.0202	0.660***
	(0.385)	(0.274)	(0.138)	(0.0787)
Skill intensity (average wage to total employees)	0.836***	0.926***	0.908***	0.795***
	(0.00701)	(0.0600)	(0.0354)	(0.0795)
Formal training	0.117	0.222	0.171	0.319***
	(0.386)	(0.262)	(0.199)	(0.0587)
Import of inputs	0.382***	0.101	0.317***	0.708***
	(0.113)	(0.295)	(0.0472)	(0.0441)
Export status	0.991***	3.288*	1.082***	0.900***
	(0.111)	(1.680)	(0.135)	(0.0721)
Constant	2.917***	3.523***	4.351***	3.310***
	(0.814)	(0.369)	(0.117)	(0.423)
Observations	336	123	317	142
Year-FE	Yes	Yes	Yes	Yes
Sector-FE	No	No	Yes	Yes

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5.3 Alternative Measure of Productivity

This section introduces a sensitivity analysis using an alternative measure of productivity to check whether the baseline results are robust. We followed a number of seminal works, including Amiti and Konings (2007); Amiti and Wei (2009); and Görg, Hanley, and Strobl (2008), by using the log of value added per worker as a proxy for labor productivity. For specification with labor productivity, we included capital intensity measured by the log of the real value of capital stock. The estimation results are given in Table 4.

The estimate is generally robust and consistent. We find that the variables of age, foreign ownership, access to finance, training, imported input intensity, and export have a positive impact on productivity. We also observe that the coefficient of skill is positive; however, it is statistically insignificant in this specification. If we replace average wage per employee to capture skill intensity in the estimation, it turns positive and becomes significant. We also find a positive association between capital intensity and labor productivity. Most importantly, the coefficients of both foreign technology and process innovation are strongly positive as in the baseline results. For ICT infrastructure, we find that this specification has no significant impact on productivity.

Table 4: Estimation Results for Technology, Innovation and Labor Productivity

Variables	(1) Labor Productivity	(2) Labor Productivity
Age	0.282***	0.122
	(0.106)	(0.153)
Foreign ownership	0.609***	0.213***
	(0.0830)	(0.00143)
Access to finance	0.504***	0.351
	(0.0650)	(0.279)
*Foreign technology	0.651***	0.299**
	(0.220)	(0.139)
ICT infrastructure	0.113	–0.00517
	(0.114)	(0.211)
Process innovation	0.266**	0.115
	(0.134)	(0.140)
Skill intensity (share of skilled labor)	0.00150	
	(0.00196)	
Skill intensity (average wage to total employees)		0.858***
		(0.0284)
Formal training	0.567***	0.327**
	(0.118)	(0.130)
Capital intensity	0.220***	0.113**
	(0.0684)	(0.0492)
Share of imported input	0.00407*	0.00199***
	(0.00238)	(0.000138)
Export status	0.716***	0.829***
	(0.0409)	(0.0484)
Constant	–6.911***	–4.433***
	(0.0935)	(0.147)
Observations	433	432
R-sq	0.8786	0.9402
Year-FE	Yes	Yes
Sector-FE	Yes	Yes

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5.4 Addressing Endogeneity Problems

Our econometric specification might encounter an endogeneity issue because innovation and technology variables are endogenous due to the reverse causality in our model. The preceding analysis suggests that innovative firms are more productive than non-innovative firms and that firms with higher technological capacities are more productive. However, the relationship could be the opposite with firms that have higher productivity tending to invest more in innovation and technology. The potential reverse causality between innovation, technology, and productivity represents endogeneity issues that cause the ordinary least-square estimate to be biased. To address the endogeneity concerns, we applied the IV method to estimate equation (5) using the two-stage least-square (2SLS) estimator—the most common strategy that researchers use to address the endogeneity problem (Bascle 2008; Wooldridge 2016). We adopted the strategy used by Li, Jin, and Ding (2019) to identify the instrument variables by averaging the value of the innovation variable (technology licensed from a foreign-owned company) and the value of the technology variable for each region where

sample firms are located. In our dataset, the surveyed firms were randomly selected from five geographical areas in which average values for innovation and foreign technology adoption varied considerably. The selection of instruments was based on the intuition that the regional innovative capacity and ecosystem are highly connected with firm innovation but weakly correlated with firm productivity (Li, Jin, and Ding 2019). Likewise, the foreign technology adoption trends in each region strongly affect firm technology adoption strategy but are weakly associated with firm productivity.

Table 5 presents the results of the IV estimation. The Sargan test result suggests that there is no overidentifying problem, indicating that our instrument variables are effective. The results from the 2SLS regression are similar to the baseline estimation. Except for the coefficients of age, which are positive but statistically insignificant, other firm characteristics have positive and significant impacts on firm productivity, including the characteristics of foreign ownership, access to finance, skill intensity and training, and import and export. Like the baseline results, firms that introduce process innovation in the production tend to have higher productivity. Firms that obtain a technology license from overseas and those that have better ICT infrastructure are also more productive. In summary, the estimation that accounts for the endogeneity issue provides robust evidence about the positive relationship between innovation, technology, and productivity.

Table 5: Results for Technology, Innovation, and Productivity using 2SLS Estimator

	(1)
Variables	**2SLS**
Age	0.0473
	(0.117)
Foreign ownership	0.622***
	(0.165)
Access to finance	0.455***
	(0.150)
Foreign technology	0.340**
	(0.168)
ICT infrastructure	0.405***
	(0.151)
Process innovation	0.247*
	(0.133)
Skill intensity	0.881***
	(0.0445)
Formal training	0.252*
	(0.149)
Imported input (dummy)	0.510***
	(0.169)
Export status (dummy)	1.058***
	(0.187)
Observations	459
R-sq	0.642
Sargan statistic	0.835
p-value	0.6586
Year-FE	Yes
Sector-FE	Yes

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

6. CONCLUSION

This paper examines the effect of innovation and technology on productivity using unbalanced panel firm-level data from Cambodia's enterprise survey from the World Bank. We adopted the following empirical strategies: (1) estimating productivity based on the Cobb-Douglas production function using the semi-parametric method developed by Levinsohn and Petrin (2003); and (2) regressing the derived productivity with innovation, technology, and other firm characteristic variables. Innovation was proxied by the introduction of new technology that has substantially changed the way the main product is produced, whereas technology was measured by two variables, namely a technology license acquired from a foreign company and ICT infrastructure. The results suggest that innovative and technological capabilities are the important variables that contribute to productivity improvement. Firms that are innovative in production and have better technology and ICT infrastructures tend to have higher productivity levels. We also found evidence that technology obtained through foreign ownership and imported intermediate inputs positively contributes to increases in productivity.

We also assessed the effects on productivity of human capital, exposure to foreign markets through exports, and access to finance. We find robust evidence that skill, training, export activity and access to finance are positively correlated with productivity. The findings highlight the significant contributions that human capital, participation in both downstream and upstream production activities, and financing make in helping firms raise productivity.

Since productivity is the main driver of industrial transformation and economic growth, it is extremely important for least developed countries like Cambodia to enhance the productivity and competitiveness of its enterprises. The following might be important policy considerations for fostering productivity:

- First, the domestic capacity to absorb foreign technologies and effectively participate in the production activities of Foreign Direct Investment (FDI) is critical to increase the productivity of domestic firms.
- Second, it is fundamental in fostering productivity to induce technology transfer and invest in expansion of a more comprehensive and reliable ICT infrastructure to foster productivity. FDI is known as an effective agent of technology transfer to the domestic economy. The government might consider providing extra incentive to technology-driven FDI that has a high technology spillover to domestic enterprises. There is also a need to improve the competitiveness of Special Economic Zones (SEZs) to attract multinational activities and establish higher quality SEZs as well as science parks to attract technology-driven FDI into the Cambodian economy.
- Third, our results indicate the importance of innovation and the need to support the innovative capacities of firms. This requires the financing and promotion of national research capacity and development, support for industrial research collaboration between academia and the private sector, and increased access to finance for innovation activities. It is also important to promote research incubation and technological and innovative platforms for the private sector.
- Fourth, our findings indicate the importance of foreign ownership and international networks in helping firms to enhance productivity. This is because multinational corporations are key actors in the production networks and their presence can support and facilitate domestic firms. Our empirical results imply the important role of global value chains (GVCs) and the impact of exports and

imports on firm productivity improvement. The results indicate the importance of trade and investment facilitation as critical to increase GVC activities and their impact on firm performance.

- Fifth, the results indicate that the domestic capacity of human capital in terms of skills and training is an important resource that can foster firm productivity. There is a need for Cambodia to have a coherent and cohesive educational vision, aligning educational policies with industrial development strategy and establishing regular and structured collaborations among government ministries, training institutions, and industry. Apart from building the quality of general education which is a prerequisite condition for human capital development, the government might consider aggressively expanding technical and vocational training programs to sharpen the skills of the workforce that are of great use in the value chain production. It is also crucial for educational institutions to ensure that training curricula and standards are in line with industrial skill needs. Our finding also suggests the importance of in-house training. The government should scale up the "training funds" that domestic firms, including SMEs, could use to develop the skills of their workers. Successful human capital development requires active participation and collaboration between the government and the private sector. Key roles of the government include collaborations with stakeholders, such as the private sector, industry associations, and educational institutions (public–private partnerships); financial support for education and training through such programs as tax incentives and scholarship programs; and regulation of training quality through flexible skills accreditation. Firms should increase their partnerships with educational institutions to provide internships and training to students to improve their technical and vocational education and skills. Equally important is the provision of ongoing in-house formal training to improve the relevance of the skills of workers.

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