BACKGROUND PAPER

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Sameer Khatiwada and Rosa Mia Arao

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HUMAN CAPITAL AND INNOVATION AT THE FIRM-LEVEL

Sameer Khatiwada
Technology and Innovation Specialist (Social Sectors), Southeast Asia Department, Asian Development Bank (ADB).

and

Rosa Mia Arao
Consultant, Economic Research and Regional Cooperation Department, ADB

Abstract

This paper analyzes the relationship between human capital and firm-level innovation using data from the World Bank's Enterprise Survey covering 26,855 firms in manufacturing, retail, and services. It examines whether the level of education of workers, managerial experience, and in-firm training have a positive association with firm-level innovation. Moreover, this paper explores in greater detail how the combination of employee schooling and training boost the firm's propensity to engage in innovation and how training becomes relevant, especially for firms facing constraints related to education and skills. Probit regression results show that the firm's human capital is positively associated with the firm's propensity to innovate. We also find that providing training to employees has a larger effect size compared with other measures of human capital, especially for firms facing constraints to their operations due to inadequately skilled workers.

CONTENTS

I. INTRODUCTION

Innovation is a significant source of growth and a necessary condition for competitiveness (Romer 1990, Aghion and Howitt 1992, and Aghion et al. 2014). At the firm-level, an extensive empirical literature highlights the positive impact of firm-level innovation, including research and development (R&D) activities, on firm performance and productivity (Hall et al. 2009, Harrison et al. 2008, Mairesse et al. 2005, and Raffo et al. 2008). Human capital is an essential part of innovation. It supports the absorptive capacity of firms to new knowledge and, at the same time, allows firms to develop new knowledge (Cohen and Levinthal 1990 and Smith et al. 2005). The firm's human capital endowment is an essential determinant of its ability to innovate. Even if firms only wish to imitate or implement technologies and products already available elsewhere, they still need a workforce with the relevant skills and knowledge.

Previous studies find a robust positive association between human capital and innovation output, but their measures of human capital are often restricted to formal schooling (Ayyagari et al. 2011, Robson et al. 2009, and Toner 2011). A strand of literature also shows that increasing the stock of human capital through firm-sponsored training leads to more innovation (Dostie 2018). Van Uden et al. (2016) find that employee schooling and providing training and slack time increase the level of human capital within the firm, and positively influence the innovative output of that firm. A new study by Bloom et al. (2019) shows that R&D tax credits and direct public funding may boost innovation in the short run; however, increasing the supply of human capital is still a more effective way in the long-run.

Few studies have examined how human capital drives innovation at the firm-level. Most studies focus on firm size, age, technology acquisition, and R&D activities as determinants of innovation (Hall 2009 and Almeida and Fernandes 2008). Building on the work of Van Uden et al. (2016), we explore the relationship between human capital endowment (the level of employee schooling) and firm-level practices (the provision of training to employees) and innovation at the firm-level. As most innovation in developing countries is incremental, we focus on the role of broader workforce skills in the innovation process instead of the highest-skilled workers such as scientists, engineers, and technologists referred to as human resources for science and technology (HRST). Moreover, we also take into account the industry-specific experience of the top manager, primarily neglected but important firm attribute for innovation activities. Balsmeier and Czarnitzki (2014) find a robust positive relationship between manager experience and the decision to innovate, with effects more pronounced for firms in institutionally less-developed countries. More experienced managers have better knowledge on how to protect new inventions from being imitated, how to cope with regulatory obstacles, or how to commercialize new products—factors essential for the firm's decision to innovate. Finally, we explore in greater detail how offering training to employees becomes more relevant, especially where the level of education and skills of the workforce is low or where firms face constraints to their operations due to inadequately skilled workers.

Our research is expected to contribute to the literature on the relationship between human capital and innovation at the firm-level. It is also expected to contribute to the cross-country literature, given that we included a large number of countries in developing Asia in our sample. Finally, the study also allows us to provide operationally relevant recommendations on how best to promote innovation in developing Asia based on our results. As ADB engages with countries in finding innovative solutions (technology-driven or not) to the development challenges they currently face, it is ever more critical to highlight what works in innovation.

II. METHODS

A. Data

We use data from the World Bank Enterprise Survey, which collects information on the development of new or significantly improved products and processes, (R&D) spending, and technology use. Since the innovation survey is incorporated in the general enterprise survey, data on innovation can be related to a broader set of firm-level characteristics. The survey uses a stratified random sampling method, stratified by firm size, business sector, and geographic region within a country.

We use the World Bank Enterprise Survey because it covers many countries in developing Asia. More importantly, it uses a standard survey questionnaire, similar sampling methodology, and population of inference, which translate to comparable information on several firm-level variables across countries. Our final sample covers 26,855 firms from manufacturing, retail, and services sector from 27 countries in developing Asia.[1] Table 1 shows all covered countries in our sample, the number of firms per country by size and region. For each economy, we use the latest available enterprise survey.

Table 1: Sample Composition

Region	**Country**	**Firm Size**			**Total**
		Small (<20)	**Medium (20–99)**	**Large (100+)**	
Central and West Asia *(n=2729)*	Armenia (2013)	179	135	46	360
	Azerbaijan (2013)	214	143	33	390
	Georgia (2013)	247	87	26	360
	Kazakhstan (2013)	308	219	73	600
	Kyrgyz Republic (2013)	114	119	37	270
	Tajikistan (2013)	199	124	36	359
	Uzbekistan (2013)	152	143	95	390
East Asia *(n=3060)*	China, People's Republic of (2012)	625	1,084	991	2700
	Mongolia (2013)	200	126	34	360
South Asia *(n=13725)*	Afghanistan (2014)	270	112	28	410
	Bangladesh (2013)	507	514	421	1442
	Bhutan (2015)	156	82	15	253
	India (2014)	3,065	4,028	2,188	9281
	Nepal (2013)	293	140	49	482
	Pakistan (2013)	536	451	260	1247
	Sri Lanka (2011)	322	179	109	610
Southeast Asia *(n=6999)*	Cambodia (2016)	194	118	61	373
	Indonesia (2015)	484	451	385	1320
	Lao People's Democratic Republic of (2016)	217	104	47	368
	Malaysia (2015)	347	343	310	1000
	Myanmar (2016)	363	160	84	607
	Philippines (2015)	464	504	367	1335
	Thailand (2016)	400	324	276	1000
	Viet Nam (2015)	376	352	268	996
The Pacific *(n=342)*	PNG (2015)	13	33	19	65
	Solomon Isl. (2015)	64	67	20	151
	Timor-Leste (2015)	88	30	8	126
Total		**10,397**	**10,172**	**6,286**	**26,855**

Note: Year after the country name indicates survey year.
Source: World Bank Enterprise Survey.

[1] From our sample, we exclude five countries in the Pacific (Fiji, Micronesia, Samoa, Tonga, and Vanuatu) without data on innovation variables.

B. Empirical Specification

To analyze the association between human capital with the firm's propensity to innovate, we first estimate the likelihood of the firm being innovative, controlling for broad firm characteristics. Thus, for firm *i* in industry *j* and country *c*, we have

$$Innovate_{ijc} = FC_{ijc} + I_j + I_c + \epsilon_{ijc} \qquad (1)$$

where $Innovate_{ijc}$ is a dummy variable equal to one if the firm introduced either a new product or process. We consider three broad measures of innovation: (i) *product innovation* or the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses;[2] (ii) *process innovation* or the implementation of a new or significantly improved production or delivery method, which includes significant changes in techniques, equipment, and/or software; and (iii) *product or process innovation*, which refers to whether the firm introduced either a new product or process.

FC_{ijc} is a vector of firm characteristics that have been shown in the literature to affect the firm's propensity to innovate, such as firm size, number of years in operation, foreign ownership, exporting activity, and R&D. I_j are industry variables, I_c are country variables, and ϵ_{ijc} captures unobserved firm, industry, and country characteristics. Since our dependent variable is binary, we use maximum likelihood (probit) to estimate equation (1).

We then introduce measures of human capital (HC_{ijc}) into the regression to examine the association with the firm's innovative activities. Again, we estimate equation (2) using maximum likelihood (probit).

$$Innovate_{ijc} = FC_{ijc} + HC_{ijc} + I_j + I_c + \epsilon_{ijc} \qquad (2)$$

In our specification, we consider three broad measures of human capital. First is the share of employees that completed high school, which is a proxy for the stock of generic skills and basic knowledge available within the firm. A higher share of schooled employees represents a better ability of the workforce to adopt, adapt and diffuse new or improved products and production processes (Toner 2011). Thus, we hypothesize that the higher the share of employees who completed at least high school education, the higher the probability of engaging in innovation activities.

Second, we include the number of years of experience of the top manager working in the industry. The top manager refers to the highest-ranking management individual in the firm and could be the owner if he/she works as the manager of the firm. This variable captures the role more senior, more experienced people have on innovative output. We hypothesize that the higher the industry-specific experience of the top manager, the higher is the likelihood to engage in innovation.

Finally, we consider firm-level practices that can increase or develop the level of human capital within the firm, such as providing training to employees. In our data, formal training includes classroom work, seminars, lectures, workshops, and audiovisual presentations and demonstrations with a structured and defined curriculum.[3] Formal training can update or upgrade employees' knowledge, but more importantly, provide employees specific knowledge not learned

2 This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness, or other functional characteristics.

3 It does not include training to familiarize workers with equipment and machinery on the shop floor, training aimed at familiarizing workers with the establishment's standard operating procedures, or employee orientation at the beginning of a worker's tenure.

from general education. Again, we expect that a firm that provides training to its employees has a higher likelihood of engaging in innovation compared to firms that do not provide formal training.

Further, we also include an interaction term that captures how formal training can compensate for the lower degree of education of the workforce. We expect that training will be pivotal, especially for firms facing constraints to doing business due to an inadequately educated workforce (eq. 3). Moreover, we hypothesize that the interaction employee schooling and formal training leads to a higher propensity to innovate (eq. 4).

$$Innovate_{ijc} = FC_{ijc} + HC_{ijc} + training\#skills_{constraint} + I_j + I_c + \epsilon_{ijc} \quad (3)$$

$$Innovate_{ijc} = FC_{ijc} + HC_{ijc} + training\#educ + I_j + I_c + \epsilon_{ijc} \quad (4)$$

III. RESULTS

The summary statistics in Table 2 indicate that about 53% of firms in our sample report to be innovative, i.e., by introducing either a new product or process. The share of firm's reporting introducing a new or significantly improved process is higher at 48% compared with only 34% of firms reporting product innovation. Only 23% of firms report spending on research and development to improve or develop products, services, or procedures. Interestingly, a considerable number of firms offered formal training to employees, around 40% of the sample. More than half (57%) of the workforce of the average firm at least holds a high school degree. Relatively experienced top managers lead firms in our sample with an average of 15 years of industry-specific experience.

For a complete list of the variables used in the regression, including variable definitions and summary statistics, refer to Table 2.

Table 2: Summary Statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
Dependent variable: Innovation						
Innovation	Dummy variable equal to 1 if the firm introduced either a new product or process in the 3 years before the survey; zero otherwise	26,736	0.527	0.499	0	1
Product innovation	Dummy variable equal to 1 if the firm introduced new or significantly improved products or services in the last 3 years; zero otherwise	26,640	0.339	0.473	0	1
Process innovation	Dummy variable equal to 1 if the firm introduced new or significantly improved process in the last 3 years; zero otherwise	25,395	0.477	0.499	0	1
Control variables						
Firm size						
Small	Equal to 1 if the firm has <20 employees; zero otherwise	27,474	0.393	0.488	0	1
Medium	Equal to 1 if the firm has 20–99 employees; zero otherwise	27,474	0.377	0.485	0	1
Large	Equal to 1 if the firm has 100+ employees; zero otherwise	27,474	0.230	0.421	0	1
Firm age						
Young	Equal to 1 if firm has been operating for 1 to 5 years; zero otherwise	27,074	0.104	0.305	0	1

Mature	Equal to 1 if firm has been operating for 6 years–15 years; zero otherwise	27,074	0.438	0.496	0	1
Old	Equal to 1 if firm has been operating for more than 15 years; zero otherwise	27,074	0.458	0.498	0	1
Foreign-owned	Dummy variable equal to one if foreigners hold at least 10% of ownership; zero otherwise	27,360	0.063	0.243	0	1
Exporter	Dummy variable equal to 1 if at least 10% of the firm's annual sales comes from direct export; zero otherwise	27,092	0.133	0.339	0	1
Research and development (R&D)	Dummy variable equal to 1 if the firm has design and R&D expenditures (e.g., labor costs with R&D personnel, materials or subcontracting costs); zero otherwise	25,567	0.226	0.418	0	1
Independent variables: Human capital						
Workforce with high school education (%)	Percentage of the full-time workers who completed high school; zero otherwise	22,847	56.549	35.369	0	100
Training	Dummy variable equal to 1 if the firm provides internal or external training to its workers; zero otherwise	26,667	0.398	0.490	0	1
Manager experience	Natural logarithm of the number of years of experience of the top manager working in the sector	26,750	2.507	0.737	0	4.263

Source: World Bank Enterprise Survey.

Table 3 reports the results of the probit regressions performed to estimate the relationship between human capital and the firm's propensity to innovate. Model (1) is the baseline regression, including only the control variables. Model (2) adds the three human capital measures. Model (3) measures the varying effects of training for firms facing skills-constraint as an obstacle to doing business. Model (4) adds the interaction effects between employee schooling and training. As a robustness check, we also explore an alternative estimation model using ordinary least squares (linear probability model). We find that the probit regression results are consistent with the results of the linear probability model (Appendix 1).

With regard to our control variables, results are in line with the literature. We find that the likelihood to engage innovation is increasing in firm size, such that medium and large firms are more likely to introduce a product or process innovation compared with small firms. Marginal effect analyses show that medium and large firms are 7.2 percentage points and 13.3 percentage points more likely to report either product or process innovation than small firms, respectively (Model 1; Table 4). R&D positively influences innovative outcomes—firms that spend on R&D activities are up to 40.8 percentage points more likely to innovate. Firms who export are 3.2 percentage points more likely to engage in either product or process innovation than firms selling only to the domestic markets.

Table 3: Probit Regression Results

Variables	Either Product or Process Innovation				Product Innovation				Process Innovation			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
Medium (default: small)	0.234***	0.213***	0.211***	0.213***	0.179***	0.149***	0.149***	0.149***	0.239***	0.226***	0.224***	0.226***
	(0)	(0)	(0)	(0)	(3.87e-10)	(8.61e-07)	(6.85e-07)	(8.18e-07)	(0)	(0)	(0)	(0)
Large (100+)	0.437***	0.353***	0.353***	0.353***	0.318***	0.238***	0.237***	0.238***	0.453***	0.376***	0.375***	0.376***
	(0)	(0)	(0)	(0)	(0)	(7.41e-08)	(1.23e-07)	(7.85e-08)	(0)	(0)	(0)	(0)
Mature (default: young)	0.0591*	0.0502	0.0524	0.0498	0.0734**	0.0781**	0.0806**	0.0776**	0.0763**	0.0557	0.0560	0.0553
	(0.0939)	(0.228)	(0.213)	(0.232)	(0.0220)	(0.0342)	(0.0316)	(0.0357)	(0.0420)	(0.182)	(0.184)	(0.185)
Older	0.0859**	0.0613	0.0593	0.0610	0.118***	0.104**	0.104**	0.104**	0.0616	0.0280	0.0251	0.0277
	(0.0169)	(0.120)	(0.131)	(0.122)	(0.00366)	(0.0159)	(0.0165)	(0.0161)	(0.127)	(0.504)	(0.549)	(0.508)
Foreign-owned	0.00999	-0.0491	-0.0488	-0.0515	0.0828	0.0490	0.0524	0.0476	-0.0266	-0.0516	-0.0506	-0.0533
	(0.845)	(0.380)	(0.387)	(0.355)	(0.104)	(0.384)	(0.352)	(0.398)	(0.597)	(0.345)	(0.357)	(0.328)
Exporter	0.107***	0.101**	0.0978**	0.101**	0.0543	0.0278	0.0265	0.0284	0.0958***	0.0948***	0.0908**	0.0951***
	(0.00397)	(0.0132)	(0.0163)	(0.0131)	(0.105)	(0.441)	(0.466)	(0.429)	(0.00498)	(0.00823)	(0.0111)	(0.00812)
Research and development	1.353***	1.284***	1.284***	1.283***	1.039***	0.979***	0.977***	0.979***	1.282***	1.199***	1.201***	1.198***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Workforce with high school education (%)		0.00140**	0.00135**	0.00113		0.00136**	0.00137**	0.00109*		0.000958	0.000942	0.000740
		(0.0297)	(0.0356)	(0.113)		(0.0127)	(0.0125)	(0.0952)		(0.136)	(0.145)	(0.300)
Training		0.244***	0.214***	0.198***		0.235***	0.201***	0.197***		0.244***	0.233***	0.209***
		(1.59e-10)	(4.35e-07)	(0.00104)		(0)	(4.81e-09)	(0.00219)		(3.01e-09)	(1.54e-07)	(0.000754)
Manager experience		0.0390**	0.0382**	0.0395**		0.0471***	0.0468***	0.0477***		0.0275	0.0269	0.0279
		(0.0268)	(0.0339)	(0.0248)		(0.00618)	(0.00712)	(0.00569)		(0.162)	(0.179)	(0.154)
Skills constraint			0.0588				-0.0654				0.0844*	
			(0.244)				(0.322)				(0.0774)	
Training * skills constraint			0.199**				0.235***				0.0397	
			(0.0139)				(0.00216)				(0.640)	
Training * high school education				0.000803				0.000669				0.000616
				(0.323)				(0.449)				(0.449)
Constant	0.173	-0.0331	-0.0843	-0.0191	-0.345***	-0.575***	-0.580***	-0.561***	-0.0469	-0.216	-0.256	-0.204
	(0.152)	(0.792)	(0.481)	(0.881)	(0.000647)	(3.55e-06)	(2.45e-06)	(1.13e-05)	(0.738)	(0.186)	(0.109)	(0.214)
Industry dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,952	20,714	20,610	20,714	24,883	20,670	20,567	20,670	24,700	20,532	20,428	20,532

Notes: The table reports coefficients of the probit regressions.
Robust p-values in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.
Source: Authors' calculations based on data from the World Bank enterprise surveys

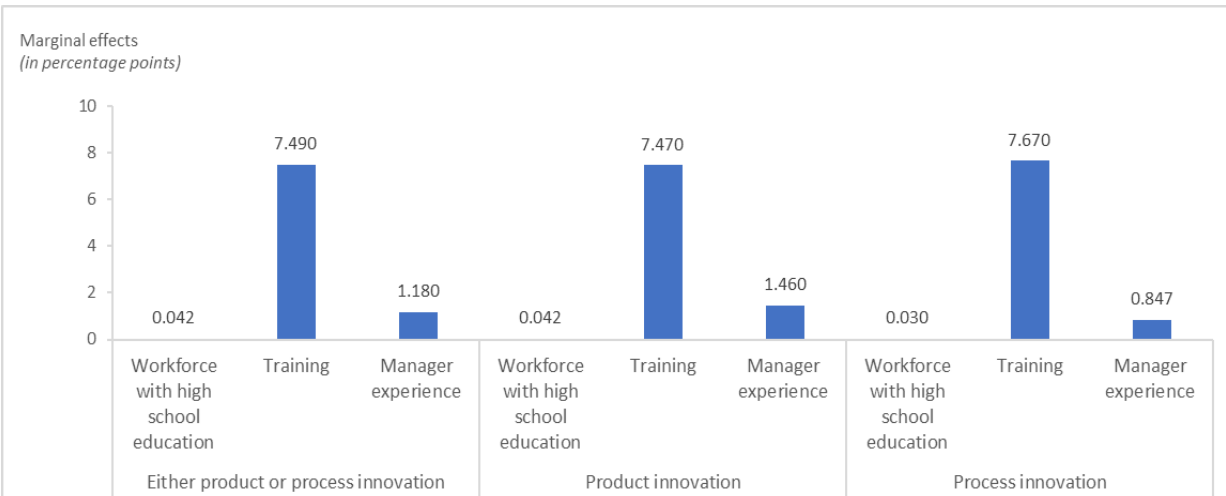
Table 4: Probit Regression Results: Marginal Effects

Variables	Either Product or Process Innovation				Product Innovation				Process Innovation			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
Medium (default: small)	0.0718***	0.0658***	0.0653***	0.0659***	0.0529***	0.0459***	0.0460***	0.0460***	0.0725***	0.0711***	0.0705***	0.0712***
	(0)	(0)	(0)	(0)	(5.36e-10)	(1.11e-06)	(8.81e-07)	(1.06e-06)	(0)	(0)	(0)	(0)
Large (100+)	0.133***	0.108***	0.108***	0.108***	0.0965***	0.0744***	0.0742***	0.0744***	0.138***	0.118***	0.118***	0.118***
	(0)	(0)	(0)	(0)	(0)	(1.18e-07)	(1.96e-07)	(1.25e-07)	(0)	(0)	(0)	(0)
Mature (default: young)	0.0177*	0.0152	0.0159	0.0151	0.0214**	0.0238**	0.0245**	0.0236**	0.0227**	0.0172	0.0173	0.0170
	(0.0944)	(0.229)	(0.215)	(0.234)	(0.0211)	(0.0332)	(0.0307)	(0.0347)	(0.0421)	(0.183)	(0.185)	(0.186)
Older	0.0257**	0.0186	0.0180	0.0185	0.0348***	0.0318**	0.0317**	0.0317**	0.0183	0.00862	0.00775	0.00855
	(0.0172)	(0.121)	(0.132)	(0.124)	(0.00324)	(0.0145)	(0.0151)	(0.0148)	(0.127)	(0.505)	(0.550)	(0.509)
Foreign-owned	0.00299	-0.0149	-0.0148	-0.0156	0.0249	0.0152	0.0163	0.0148	-0.00792	-0.0159	-0.0156	-0.0164
	(0.845)	(0.380)	(0.387)	(0.356)	(0.108)	(0.387)	(0.355)	(0.401)	(0.596)	(0.344)	(0.356)	(0.328)
Exporter	0.0322***	0.0304**	0.0295**	0.0305**	0.0163	0.00862	0.00821	0.00881	0.0287***	0.0293***	0.0280**	0.0294***
	(0.00403)	(0.0130)	(0.0161)	(0.0130)	(0.108)	(0.443)	(0.468)	(0.431)	(0.00521)	(0.00830)	(0.0112)	(0.00819)
Research and development	0.408***	0.380***	0.380***	0.380***	0.363***	0.348***	0.348***	0.348***	0.410***	0.384***	0.385***	0.384***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Workforce with high school education (%)		0.000424**	0.000410**	0.000427**		0.000421**	0.000424**	0.000427**		0.000295	0.000290	0.000298
		(0.0299)	(0.0357)	(0.0279)		(0.0121)	(0.0119)	(0.0108)		(0.137)	(0.146)	(0.131)
Training		0.0749***	0.0729***	0.0742***		0.0747***	0.0728***	0.0742***		0.0767***	0.0747***	0.0761***
		(1.62e-10)	(9.73e-10)	(1.58e-10)		(0)	(0)	(0)		(3.42e-09)	(1.18e-08)	(3.36e-09)
Manager experience		0.0118**	0.0116**	0.0120**		0.0146***	0.0145***	0.0147***		0.00847	0.00830	0.00860
		(0.0266)	(0.0337)	(0.0246)		(0.00592)	(0.00679)	(0.00544)		(0.160)	(0.178)	(0.153)
Skills constraint			0.0377***				0.0110				0.0304**	
			(0.00496)				(0.435)				(0.0421)	
Industry dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,952	20,714	20,610	20,714	24,883	20,670	20,567	20,670	24,700	20,532	20,428	20,532

Notes The table reports average marginal effects on the firm's probability to innovate from probit regressions.
Robust p-values in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.
Source: Authors' calculations based on data from the World Bank enterprise surveys.

The firm's human capital is positively associated with the firm's propensity to engage in innovation across models and three measures of innovation. Employee schooling positively influences the likelihood to engage in innovation, albeit small. Marginal effects analysis reveals that a "very small"[4] increase in the share of the workforce with high school education increases the likelihood to engage in education by 0.042 percentage points (Figure 1). The top manager's experience also increases the likelihood to engage in innovation—a small increase in the top manager's experience increases the probability of engaging in innovation by 1.2 percentage points. Similarly, we find a larger, positive association between providing training to workers and the likelihood to engage in innovation. Firms that provide formal training to employees are 7.5 percentage points more likely to engage in innovation (Figure 1).

Figure 1: Human Capital and Innovation



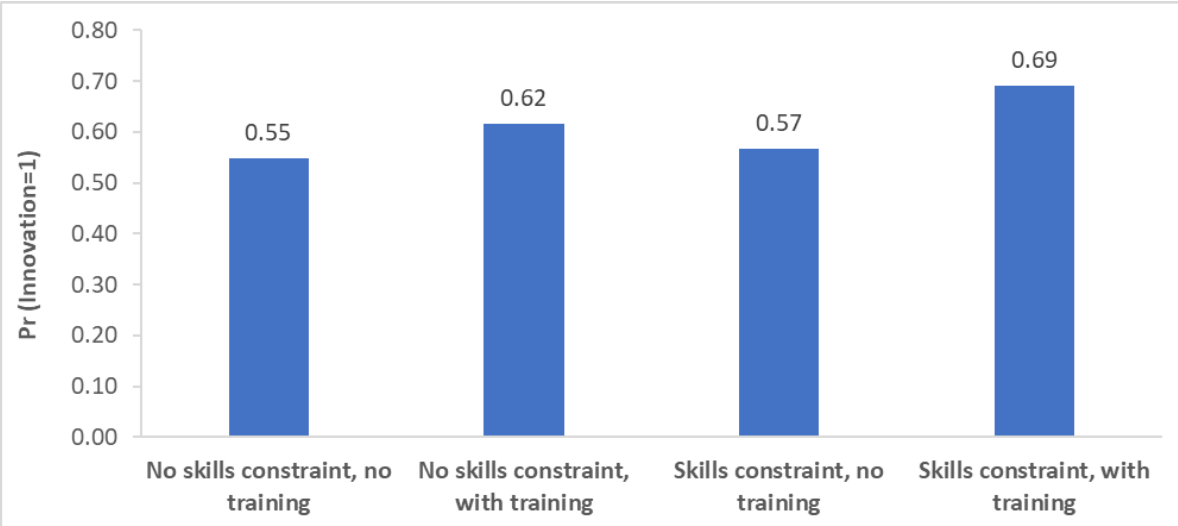
Source: Authors' calculations based on data from the World Bank enterprise surveys.

Moreover, we find that training is positively related to innovation, especially for firms who report facing constraints related to the skills and education of the workforce. Training increases the likelihood to engage in innovation by 6.6 percentage points for firms that do not face severe or very severe skills constraints (Figure 2). In contrast, skills-constrained firms that provide training to employees are up to 12.4 percentage points more like to engage in innovation compared with firms that do not provide training. In this regard, formal training can be perceived as the firm's mechanism to compensate for the constraints to doing business as a result of an inadequately educated workforce.

We do not find evidence for the hypothesis that the combination of training and employee schooling would result in higher likelihood to engage in innovation (Model 4) as indicated by the insignificant interaction term in Table 3.

[4] Cameron and Trivedi (2010) suggest this "very small amount" as the standard deviation of the variable divided by 1,000.

Figure 2: Likelihood of Innovation among Firms Facing SkillsConstraints



Source: Authors' calculations based on data from the World Bank enterprise surveys.

IV. LIMITATIONS

The results of this paper come with key data caveats. First, for each economy, we only use a single year of data. Thus, this paper cannot go beyond establishing an association between human capital and firm-level innovation. Second, our measure of innovation comes from yes/no responses of firm managers or owners on whether they introduced a new or substantially improved product or process in the past 3 years. There is great subjectivity on what constitutes as a new or significantly improved product or process. Thus, the lack of follow-up questions that can provide details to guide the veracity and accuracy of answers may result in an inaccurate picture of firm-level innovation activity and may also overestimate innovation rates (Cirera and Muzi 2016). Third, the data only covers formal firms, and a significant proportion of firms in developing Asia are informal. Finally, the measures of human capital used here is limited by data availability.

V. KEY MESSAGES

- Our results show that the firm's human capital—measured by the percentage of the workforce with high school education, incidence of on-the-job training, and managerial experience—positively influences the likelihood to engage in innovation. Similar to the results of other studies, we find that the quality of the firm's human capital is particularly important to capture the firm's absorptive capacity to new technology and knowledge (Almeida 2006, Comin and Hobjn 2004, Lederman and Maloney 2003, and Keller 2005).
- Overall, we find that providing training to employees has a larger effect size compared with other measures of human capital, especially for firms facing constraints to their operations because of inadequately skilled workers.
- Finally, we do not find evidence on the interaction effects of training and employee schooling.

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APPENDIX 1: ROBUSTNESS CHECK

As a robustness check, we also explore an alternative estimation model using ordinary least squares (linear probability model). We find that the probit regression results are consistent with the results of the linear probability model (Table A1).

Table A1: Linear Probability Model Regression Results

Variables	Either Product of Process Innovation				Product Innovation				Process Innovation			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
Medium (default: small)	0.0758***	0.0706***	0.0699***	0.0707***	0.0513***	0.0439***	0.0440***	0.0440***	0.0753***	0.0748***	0.0741***	0.0749***
	(0)	(0)	(0)	(0)	(6.00e-09)	(4.57e-06)	(3.73e-06)	(4.42e-06)	(0)	(0)	(0)	(0)
Large	0.133***	0.109***	0.108***	0.109***	0.0945***	0.0713***	0.0713***	0.0712***	0.138***	0.117***	0.116***	0.117***
	(0)	(0)	(0)	(0)	(0)	(5.95e-07)	(8.20e-07)	(6.18e-07)	(0)	(0)	(0)	(0)
Mature (default: young)	0.0154	0.0129	0.0136	0.0127	0.0223**	0.0258**	0.0266**	0.0257**	0.0209*	0.0161	0.0164	0.0160
	(0.141)	(0.311)	(0.292)	(0.315)	(0.0168)	(0.0259)	(0.0239)	(0.0269)	(0.0545)	(0.212)	(0.208)	(0.215)
Older	0.0241**	0.0172	0.0168	0.0171	0.0352***	0.0333**	0.0332**	0.0332**	0.0166	0.00772	0.00715	0.00766
	(0.0227)	(0.148)	(0.155)	(0.149)	(0.00360)	(0.0133)	(0.0141)	(0.0135)	(0.155)	(0.545)	(0.577)	(0.548)
Foreign-owned	0.00710	-0.00980	-0.00953	-0.0102	0.0164	0.00637	0.00741	0.00603	-0.00813	-0.0157	-0.0155	-0.0160
	(0.643)	(0.566)	(0.580)	(0.548)	(0.280)	(0.711)	(0.666)	(0.727)	(0.579)	(0.343)	(0.352)	(0.333)
Exporter	0.0282***	0.0261**	0.0251**	0.0263**	0.0159	0.00643	0.00603	0.00656	0.0275***	0.0270**	0.0258**	0.0271**
	(0.00811)	(0.0234)	(0.0284)	(0.0228)	(0.120)	(0.559)	(0.586)	(0.549)	(0.00634)	(0.0109)	(0.0145)	(0.0107)
Research and development	0.387***	0.359***	0.360***	0.359***	0.384***	0.362***	0.362***	0.362***	0.407***	0.376***	0.377***	0.376***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Workforce with high school education (%)		0.000444**	0.000432**	0.000374		0.000479***	0.000483***	0.000421**		0.000326*	0.000321	0.000272
		(0.0254)	(0.0301)	(0.106)		(0.00373)	(0.00362)	(0.0253)		(0.0990)	(0.107)	(0.226)
Training		0.0750***	0.0671***	0.0639***		0.0771***	0.0650***	0.0679***		0.0782***	0.0748***	0.0696***
		(3.97e-09)	(1.67e-06)	(0.000658)		(0)	(1.36e-08)	(0.00139)		(1.90e-08)	(5.18e-07)	(0.000500)
Manager experience		0.0124**	0.0121**	0.0125**		0.0161***	0.0158***	0.0162***		0.00954	0.00937	0.00965
		(0.0259)	(0.0328)	(0.0243)		(0.00292)	(0.00366)	(0.00277)		(0.129)	(0.145)	(0.124)
Skills contraint			0.0202				-0.0215				0.0269*	
			(0.243)				(0.274)				(0.0937)	
Training * skills constraint			0.0500**				0.0857***				0.0122	
			(0.0255)				(0.000547)				(0.620)	
Training * high school education				0.000193				0.000161				0.000150
				(0.419)				(0.568)				(0.547)
Constant	0.567***	0.504***	0.487***	0.507***	0.370***	0.293***	0.290***	0.296***	0.488***	0.432***	0.418***	0.434***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Sector dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,952	20,714	20,610	20,714	24,883	20,670	20,567	20,670	24,700	20,532	20,428	20,532

Notes: The table reports coefficients of the linear probability model regressions.
Robust p-values in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.
Source: Authors' calculations based on data from the World Bank enterprise surveys.