

Skill improvement by product imitation

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Abstract

This article investigates how the process of product imitation affects skill improvement for small and medium-sized enterprises (SMEs) in developing countries. By distinguishing between sources of information inputs in the imitation process, we identify two types of product imitation—reproduction and adaptation. We argue that compared to reproduction, adaptation is more likely to enhance imitators' skills. This is because adaptation requires imitators to use information from a variety of sources, which in turn creates more opportunities to gain knowledge and practice complex skills, such as trial-and-error and problem-solving. We find supporting empirical evidence by analyzing SMEs in nine developing countries. Our results indicate that SMEs can achieve skill improvement by imitating products. This finding also suggests that policies guiding SMEs toward adaptation and away from reproduction are likely to enhance SMEs' long-term growth by enabling skill improvement.

Keywords

Skill upgrading, Imitation, SMEs, Developing countries, New product development, Learning by doing

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1. Introduction

The growth of small and medium-sized enterprises (SMEs) drives economic progress in developing countries. Statistics from the Asian Development Bank, surveying about 20 countries in Asia, show that SMEs account for about 96% of all registered firms and 62% of employment (Yoshino and Taghizadeh-Hesary 2018). Similar figures can also be observed in African countries (Abor and Quartey 2010). SMEs grow mainly by introducing new products (Ansoff 1965; Goedhuys and Sleuwaegen 2010; Cassiman and Golovko 2011; Golovko and Valentini 2011), particularly through product imitation rather than innovation, as in the case of SMEs from developing countries (Kim 2001; Lee and Lim 2001; Kim, Shi, and Gregory 2004; Kale and Little 2007; Mateut 2018). Imitation can be an effective growth strategy (Luo, Sun, and Wang 2011), but over time, the growth effect of imitation wanes (Aghion and Howitt 2006; Liao 2020). Imitators need to improve their skills to enable innovation so as to ensure sustainable growth (Doha, Pagell, Swink, and Johnston 2018).

Although adopting technology (Berman, Bound, and Griliches 1994; Autor, Katz, and Krueger 1998; Gallego 2012) and investing in R&D (Berman et al. 1994; Machin and Van Reenen 1998) are two common ways to achieve skill improvement, they require financial investment and prior knowledge. Due to limited access to credit (Taymaz and Üçdoğruk 2009) and lack of relevant knowledge (Bagachwa 1992; Huang, Makoju, Newell, and Galliers, 2003), SMEs in developing countries often find it difficult to commit to R&D investment and technology adoption. As an alternative, this article proposes that SMEs in developing countries can engage in product imitation via learning by doing to improve their skills.¹ Most SMEs in developing countries already practice product imitation (Kim 2001; Lee and Lim 2001; Kim et al. 2004; Kale and Little 2007; Mateut 2018). Improving skills by imitating products requires only marginal additional resources, if any at all.

Skill improvement can occur during the imitation process (Kim and Nelson 2000). Some imitators eventually become innovative (Hobday 1995; Kim 1997, 2001; Kale and Little 2007). Classic examples include Asian Tiger firms such as Samsung (Kim 1997), Anam, RJP, Wearnes Hollingsworth Group, and Microelectronics Technology Inc. (Hobday 1995). Recent examples include Tencent, Xiaomi, and Ranbaxy in China and India. However, imitation can also trap firms in their current situations and prevent them from becoming innovative (Benhabib, Perla, and Tonetti 2014). Kim, Park, and Lee (2013) compiled a list of 10 major Chinese firms that published pirated games copied from Korean game developers. After imitating games for a

¹ Throughout this article, we use “product” to refer to “product and/or service”.

few years, some of them were able to develop their own games, but others remained imitators. Thus, not all imitation leads to skill improvement.

Analyzing SMEs in nine lower-income countries from the *Innovation Follow-Up Survey* and *Enterprise Survey* (both conducted by World Bank), we observe that not all product imitators enjoy skill improvement.² The *Innovation Follow-Up Survey* distinguishes between two types of product imitation according to whether firms reproduce or adapt an existing product sold by other firms (i.e. the target product). In the case of reproduction, imitators copy almost all product features from the target product. To adapt, firms modify the target product to fit their needs and constraints. Our empirical results show that compared to reproducers, adapters are more likely to experience skill improvement. We infer from this that adaptation allows imitators more opportunity to gain knowledge and practice more complex skills than those needed for routine tasks. This is because the adaptation process requires imitators to incorporate information from a variety of sources, while reproduction often requires information only from the target product. We have found consistent evidence to support this analysis.

One major concern about our study is the potential reverse causality between adaptation and skill improvement. It is possible that firms with higher skills choose to adapt rather than to reproduce. In fact, such a concern resonates with Linsu Kim (2001)'s three-stage framework. To describe the industrialization process in developing countries, Kim suggests that imitators start with "duplicative imitation", then progress to "creative imitation", and finally reach the stage of "innovation". He assumed that creative imitation is more difficult than duplicative imitation and requires higher skill levels. However, we argue that such an assumption is debatable, especially in lower-income countries. For example, due to limited consumer income, imitators often "creatively" simplify or leave out some product features in order to offer affordable prices (Luo et al. 2011). Creative imitation could also result from the imitator's inability to reproduce the target because of insufficient knowledge or technology. In view of these possibilities, we argue that it is not necessary that firms with higher skills adapt, or that firms with lower skills reproduce. In addition to addressing the theoretical arguments, we also try our best to address the reverse causality concern empirically. We use instrumental variables and matching approaches to check the robustness of our results. Our findings hold across different specifications.

This article contributes to the literature regarding the development of SMEs by pointing out the possibility of improving skills via product imitation. Prior studies mainly discuss how firms improve skills through technology adaptation (Berman et al. 1994; Autor et al. 1998; Gallego 2012) and R&D investments (Berman et

² This article uses the country classification suggested by the United Nations, which classifies countries in four income levels: high, upper-middle, lower-middle, and low. We use the term "higher income" to refer to high and upper-middle income, and "lower-income" for lower-middle, and low income.

al. 1994; Machin and Van Reenen 1998). In contrast, our study takes into consideration the constraints of access to financial resources and the lack of prior knowledge which most SMEs in developing countries face, proposing product imitation as an alternative means of achieving skill improvement. Our empirical findings support our proposal, demonstrating that skill improvement is likely to occur during the imitation process.

We also advance the imitation literature in various aspects. Contrary to the idea that imitation is unsustainable, our study illustrates the value of product imitation by showing how it facilitates skill improvement, which is crucial for SMEs' long-term development. This also demonstrates the growth implication of product imitation, which is largely overlooked by existing studies focusing on market performance (Kang and Suarez 2016; Giachetti, Lampel, and Pira 2017; Barreto and Baden-Fuller 2006). In addition, rather than comparing the characteristics of imitative and target products as do most of the previous studies (Kang and Suarez 2016; Lee and Zhou 2012), this article investigates the heterogeneity of the imitation process. We distinguish between the reproduction and adaptation processes of imitation based on the source of their information inputs. We have found that this feature facilitates skill improvement.

Finally, this article supplements existing studies by presenting empirical evidence from a large number of firms across a variety of industries in nine lower-income countries. Previous studies on the progression from imitation to innovation through skill improvement are mostly theoretical models (Glass 1999; Agénor and Dinh 2013; Collins 2015). Most empirical analyses have been at country or industry levels (Kale and Little 2007; Chen 2009; Wu and Mathews 2012). Firm-level studies have been mainly qualitative case studies of firms in the manufacturing sector from higher-income developing countries, with a focus on high-tech industries, such as on automotive, electronics, and telecommunications (Hobday 1995; Kim 1997; Lee and Lim 2001). Service sector firms in lower-income countries are rarely studied. This article analyzes quantitative data on SMEs in the manufacturing and service sectors from nine countries in sub-Saharan Africa and South Asia. Economic development in these countries is lower than in countries covered by previous studies, such as the Asian Tigers, India, and China. Because of the great need for economic development in lower-income countries, it is even more critical to understand how their SMEs can improve skills through imitation. Furthermore, this article analyzes firms in the low-tech manufacturing and service sectors, which are important economic sectors in lower-income countries.

2. Literature background

Innovation drives economic progress and firm growth; and imitation is a stepping stone toward innovation. Knight (1967) and Vandebussche et al. (2006) state that innovation requires higher skill levels than imitation. While imitating, firms access existing cutting-edge knowledge and information, which lays the foundation for knowledge creation and enables innovation. Studying the electronics industry imitators in Asian Tiger countries, Hobday (1995) found that firms obtained knowledge through arrangements such as joint ventures, licensing, and subcontracting. Kale and Little (2007) explained how imitators move up the R&D value chain by reverse-engineering patented drugs from advanced countries. Agénor and Dinh's (2013) formal model demonstrated that unskilled workers in the imitation sector become familiar with technology and gain cognitive skills that favor innovation. Thus, the process of imitation matters for skill development.

In particular, imitation is a channel through which information and knowledge is transferred from the target to the imitator (Zander and Kogut 1995). While imitating a product, firms select an existing product—the target product—in the market and use it as a reference for developing its own version—the imitative product. When visiting Samsung in South Korea in the 1970s, Magaziner and Patinkin (1990) found its research laboratory full of color televisions from every major company in the world. As an imitator at that time, Samsung tried to make its own color televisions by closely examining its competitors' products. Similarly, Chinese automotive firms acquire vehicles from the market in order to reverse-engineer them (Xu and Li 2014). Examining the target product gives imitators access to information regarding product features, design, and functionality, which often reflect competitors' knowledge.

Information serves as an essential input in the imitation process. Some imitators rely on information from some sources more so than others. When imitators copy all attributes of the target product (reproduction), they rely heavily on its information. This is often the case when the imitative and target products share similar contexts. Alternatively, imitators can produce a modified version of the target product (adaptation). The adapted version could simplify the target product by copying some of its attributes and forgoing others. This is often the case when imitators aim to offer the adapted version to less sophisticated, less wealthy customers. The adapted version could also combine copied attributes with their “own” attributes (Nelson and Winter 1982), which are developed in view of customer feedback, suppliers' suggestions, and internal knowledge. Allied Electronic and Magnetic, for example, an Indian company in the personal computer industry, developed dust and fungi-repellant floppy disks to meet the specific needs of their Indian customers (Atuahene-Gima and Wei 2011). Starting from manufacturing refrigerators using technology from German firms, Haier (a Chinese company in the large home

appliance industry) developed a popular washing machine which could clean not only clothes but also vegetables to satisfy consumer needs in rural China (Bonaglia, Goldstein, and Mathews 2007).

To imitate an existing product, target product information (usually offered by the competitor) is essential (Köhler, Sofka, and Grimpe 2012; Cappelli, Czarnitzki, and Kraft 2014). Such information can be obtained by acquiring the target product in the market and studying it closely. Sometimes imitators also incorporate information from other sources (Goedhuys 2007), such as customers, suppliers, and internal knowledge, in order to adapt the target product to their own needs. As demonstrated in Chen (2009), Taiwanese machine tool firms “designed” their own versions of the target product by incorporating the specific requirements of local users. Thus, we distinguish between imitation processes where firms incorporate information from the target product, and those where they incorporate information from other sources, such as customers, suppliers, and internal knowledge. When firms rely heavily on information from the target product, they reproduce the target product and copy all of its attributes. When adapting, firms incorporate information from varied sources in order to modify the target product to their own needs.

Compared to reproducers, we argue that adapters have more opportunity to acquire knowledge during the imitation process. Arrow (1962) pointed out that the need to solve new problems triggers the knowledge acquisition process, which is different from increasing efficiency due to repeatedly solving the same problem. Unlike reproducers using information from one source (i.e., the target product), adapters incorporate information from a variety of sources. The combination of different information is likely to generate new problems, as well as change the context in which problems arise. Adapters need to solve these new or similar problems in a different context. Their attempt to do so enables knowledge acquisition. We agree that it is possible that reproducers also face new problems in new contexts; however, we posit that given the introduction of one imitative product, adaptation is likely to trigger higher numbers of knowledge acquisition processes than reproduction, due to using information from a variety of sources.

In addition, we argue that the adaptation process mimics the R&D process to a greater extent than the reproduction process. As a consequence, adapters are likely to practice more complex skills than those required for performing routine tasks. On the one hand, reproducers aim to copy all product features of the target product. When the goal is achieved, the imitative product functions as expected. That is to say, there is a “guaranteed” outcome for reproducers if they are able to copy successfully the target product. Such a guaranteed success not only rarely exists in the R&D process, but also deprives reproducers of the opportunity to conduct trial-and-error experiments (Maidique and Zirger 1985) and thus learn from the process (Levitt and March 1988). On the other

hand, adapters aim to produce a modified version of the target product to satisfy their own needs. This version is not a given, but is an outcome of trial and error. The iterations of trial and error allow adapters to acquire more complex skills such as analyzing, synthesizing, and integrating information, as well as problem-solving. In their study of Indian pharmaceutical companies, Kale and Little (2007) show that patented drugs serve as a reference for guiding iterations of trial and error. Skills in searching for relevant information, identifying mistakes, and implementing solutions are enhanced during the process. Anzai and Simon (1979) also demonstrate that the ability to evaluate one's own solutions is critical to problem-solving. Thus, we expect that compared to reproducers, adapters are more likely to experience skill improvement.

3. Method

3.1 Data

Focusing on lower-income countries and covering questions about new product development processes make the *Innovation Follow-Up Survey* (World Bank 2013a) an appropriate data source for our study. We also use the *Enterprise Survey* (World Bank 2013b) for additional variables. The World Bank collects both datasets periodically using a global methodology, which enables cross-country comparison. The *Enterprise Survey* targets formal (registered) firms with five or more employees. The *Innovation Follow-Up Survey* is administered to a subset (about 75%) of firms responding to the *Enterprise Survey*. Due to changes in the questionnaire, key variables are available only from the 2013 survey (which collected data for the period of 2010 to 2012), covering nine lower-income countries: Bangladesh, the Democratic Republic of the Congo (DR Congo), Ghana, Kenya, Nepal, Pakistan, Tanzania, Uganda, and Zambia.

In total, 5,172 firms were surveyed across the nine countries. The samples are nationally representative, having been selected randomly from the original *Enterprise Survey*, and include 4,353 small and medium-sized enterprises (SMEs). This study defines SMEs as firms with fewer than 100 permanent, full-time employees, as suggested by the sampling framework of the *Enterprise Survey* (World Bank 2009). Among the SMEs surveyed, 38% (1,653 firms) introduced at least one new product during the survey period.³ Excluding observations with missing values, the final working dataset includes 1,076 SMEs engaging in imitation.

3.2 Variables

³ The questionnaire defines “new” as new to the firm but not necessarily new to the market.

Skill improvement may result from firms' existing employees becoming more skillful by training, learning by doing, or by recruiting skilled employees. Ideally, this study would have included data on employee skill levels; however, such data is not available. The *Innovation Follow-Up Survey* asked "From fiscal year 2010 through 2012, as a consequence of introducing any innovative product or service, did the number of skilled workers employed by the establishment increase, decrease or remain the same?" (World Bank 2013a: HB17).⁴ We interpret the answer to this question as an indicator of whether firms experience skill improvement due to the introduction of imitative new products. The dependent binary variable was named "skill improvement". It took the value of one when firms increased the number of skilled workers, and zero otherwise. Although this measurement cannot fully reflect the richness of the concept of skill improvement, it is the best measurement available in the survey. If increasing the number of skilled workers is obligatory for skill improvement, the measurement appropriately captures at least one key element of the process.

Based on the *Innovation Follow-Up Survey*, a firm can develop an imitative product by either reproducing or adapting an existing product sold by other firms. The independent variable "adaptation" takes a value of one when the imitator develops its product by adaptation. When the imitator reproduces, it takes the value of zero. We control for whether firms introduce a new process, which has been shown to affect skill improvement (Berman et al. 1994; Gallego 2012; Lee and Wie 2015). As defined in the questionnaire, a new process could be related to production, input logistics, output distribution, or maintenance. We named the variable "new process". It takes a value of one when the imitator introduced at least one new or significantly improved process during the survey period, and zero otherwise.

The extent to which firms can improve their skills through imitation is related to effort intensity (Kim 2001). We approximated effort intensity using internal R&D expenses and purchases of fixed assets or software for new product development (Berman et al. 1994). Since the expenses are recorded using the local currency in each country, we converted them into US dollars. To do so, we used the exchange rates and deflators calculated by Cusolito, Francis, Karalashvili, and Rodriguez Meza (2016).⁵ We further divided the converted and deflated amount by the number of employees. Then, we took the log of the final value and named the variable "investment intensity".

⁴ According to the survey manual (World Bank n.d.), workers are considered skilled when they contribute special knowledge or the ability to their work. These skills could be learned on the job or acquired from studying at college, university, or technical school. A worker is unskilled when he or she does not need "special training, education, or skill to perform their job" (p. 26).

⁵ Cusolito et al. (2016) detailed the procedure they followed to convert the local currency unit into US dollars. They first used the official exchange rate (period average) used in the World Development Indicators. Then they applied the US GDP deflator to deflate the converted results to 2009.

Another variable affecting skill improvement is the use of technology (Pavcnik 2003). The *Innovation Follow-Up Survey* asked whether the main new product was based on a technology or industrial design previously unused by the firm. We took this as evidence that developing the new product involved a technology that was new to the imitator. The binary variable “new technology” takes a value of one when the firm answered yes. We also controlled for whether firms purchased or licensed any patented or non-patented invention or knowledge when developing the new product. We named the binary variable “new knowledge”: one for yes and zero otherwise.

Other control variables included “firm size” and “firm age”. We measured the former by the number of full-time and permanent employees (in log). Firm age was the number of years since the firm registered formally, in logarithmic form. We also controlled for country, sectoral taxonomy (Peneder 2010), and sector (manufacturing or services).⁶ Ideally, we would have controlled for firm capital. However, as 50% of the values were missing, it was not feasible to include this as a control variable.

-Insert Table 1 about here-

We present our descriptive statistics in Table 1. About 45% of the imitators improved their skills. Among all imitators, 73% are adapters. About 66% of firms implement a new process. Investment intensity varied across firms. The average amount of spending was about \$86,000 (in 2009 US dollars) per employee. The median was only about \$22 (in 2009 US dollars). About 44% of firms recorded no spending on internal R&D, fixed assets, or software for the development of new products. This is consistent with the expectation that many SMEs in developing countries do not rely on R&D to develop new products. About half of the SMEs integrated new technology or industrial design in their imitative products. The proportion of firms purchasing patented or non-patented inventions or knowledge was low—about 5%. Half of the firms had fewer than 14 permanent, full-time employees. The mean firm size was 21 people. Half of the firms began operating 13 years ago, and the mean age of firms was about 17 years old.

The subsample included 782 SMEs that imitate by adapting. Based on the *t* statistics, firms that imitate and adapt were more likely to improve their skills than firms that merely reproduce. This was the only variable that differed significantly between adapters and reproducers. There were no significant differences between their mean values in terms of new processes, investment intensity, new technology, new knowledge, firm size, or firm

⁶ Based on Peneder’s (2010) sectoral taxonomy of “relative innovation intensity”, we classify firms into three categories: 1) low, 2) intermediate-to-low and intermediate, and 3) intermediate-to-high and high.

age. For these control variables, t tests supported the fact that the mean equality of the variables between these two groups of firms cannot be rejected.

-Insert Table 2 about here-

We present the coefficients of correlations among the variables in Table 2. The pairwise correlations between variables were low to moderate. The correlation coefficient between “new process” and “investment intensity” was about 0.3. Since implementing a new process often involves buying new machinery, equipment, and software, the moderate correlation between the two variables was not surprising.

4. Analysis and results

4.1 Main analysis

Since the dependent variable “skill improvement” is binary, we analyzed the data using logit model. The working data contains 1,076 observations. Table 3 report the estimated coefficients and their standard errors. Except for “new knowledge”, which is significant at 90% confidence interval, all other control variables are significant at 95% confidence interval. Consistent with the literature, new process, investment intensity, new technology, and new knowledge are all related to the likelihood of skill improvement. The estimated coefficient for “adaptation” is significant, suggesting that adaptation is positively associated with skill improvement. Adapters are more likely to improve their skills than reproducers. The odds of adapters improving its skills are about 1.7 times ($e^{0.518}=1.67$) that of reproducers, all other variables being constant.

-Insert Table 3 about here-

As suggested by Train (1986) and Hoetker (2007), it is unlikely that any single observation has the mean values of all variables. We calculate the average effect of adaptation by first predicting the probability of skill improvement for each observation and then taking the average. The probability of skill improvement is 0.50 for adapters and 0.32 for reproducers. The differences are statistically significant. While fixing other variables at their mean values, adaptation increases the probability of skill improvement by 0.12. The magnitude of the marginal effect of adaptation varies slightly across countries, ranging from 0.086 for Zambian firms to 0.128 for Kenyan firms. However, it remains stable across manufacturing and service sectors, as well as across sectoral taxonomy.

One might argue then that when firms improve their skills, they are more likely to choose adaptation, rather than arguing that adaptation results in improved skills. Previous studies have suggested that firms gain skills first

by engaging in duplicative imitation. Then, they use these skills to add new performance features to the target product, which is the definition of creative imitation (Kim 2001). As with adaptation and reproduction, creative and duplicative imitation differ in the extent or degree to which the imitative products copy attributes of the target. From this perspective, adaptation and reproduction are equivalent to creative and duplicative imitation, respectively. If this is the case, it is reasonable to raise the concern that firms choose adaptation because they have higher skill levels.

We argue that this is not the case, given the empirical context of our article. Creative imitation is defined as “producing an imitative product with new performance features” (Kim 2001: 298), thus producing something “better” (Lee and Zhou 2012: 14) than the target product. However, we do not suggest any vertical differentiation in terms of quality. That is, adaptation does not necessarily refer to improved quality or features. It could entail simplifying or reducing product features in order to offer the product at an affordable price to consumers in lower-income countries. If adaptation implies higher quality, we expect that adaptation would generate larger sales than would reproduction. However, *t* statistics show that the equality of the mean sales generated by the imitative products between adapters and reproducers cannot be rejected.⁷ Evidence from descriptive statistics also counters the argument that adapters have a higher level of skills than reproducers. We use sales per employee at the beginning of the survey period to approximate the skill level before introducing the imitative product. *T* statistics cannot reject the equality of mean sales per employee.⁸ In addition, adapters and reproducers are similar in new process, investment intensity, new technology, new knowledge, firm size, and firm age, as presented in Table 1.

4.2 Robustness check

Empirically, we use the instrumental variables approach to reduce the concern of endogeneity. The firms in our sample are imitators. They are prone to following the decisions of other firms, that is to say, their decision of whether to imitate by reproducing or adapting is likely to follow the decisions of other firms. In particular, the focal firm is more likely to adapt if other firms in the same industry and geographic area also adapt. Nevertheless, the number of adapters in the same industry and geographic area does not directly impact whether the focal firm experiences skill improvement. Therefore, we used the number of adapters located in the focal

⁷ The T test is performed based on 882 observations whose sales data was available.

⁸ Due to data availability, we converted the 2010 sales of firms in different countries using the same exchange rates and deflators as those used to calculate the variable investment intensity. We performed *T* tests of the mean differences of sales per employee between 844 firms for which 2010 sales data were available.

firm's industry and geographic area as an instrumental variable. The firms' addresses were not available. We used the country, the region within a country, and whether the firms were located in big cities within given regions to define whether firms were located in the same geographic area as the focal firm. Then we counted the number of adapters among these firms by industry, respectively. We named this instrumental variable "proximity adapters". The correlation coefficient between "proximity adapters" and "adaptation" is 0.19. We present the results of probit regression with instrumental variables in Table 4.⁹ Model 2 uses maximum likelihood and Model 3 uses Newey's (1987) minimum chi-squared (two-step) estimator. The results are consistent with the main analysis. The coefficient of "adaptation" remains positive and significant.

-Insert Table 4 about here-

We further address the endogeneity issue using coarsen exact matching (CEM) and propensity score matching (PSM). Considering "adaptation" as the treatment, we match firms based on all the control variables in the regression analysis, including "new process", "investment intensity", "new technology", "new knowledge", "firm size", "firm age", "country", "sectoral taxonomy", and "manufacturing dummy". Among the nine control variables, except for investment intensity, firm size, and firm age, all other control variables are categorical. Since there is no strong theory supporting cutting points, we rely on the automated algorithm in Stata using the command of *cem* to conduct coarsened exact matching.¹⁰ The ex-ante overall imbalance in covariates is 0.9834. After the matching process, the imbalance reduced to 0.4868. We obtained a match sample of 71 observations. To take into consideration the remaining imbalance in covariates, we apply the logit model with all control variables on the matched sample, taking into consideration the differential strata sizes. In the estimation process, Stata drops 6 observations because they predict the outcome perfectly. The variable of "new knowledge" is also dropped due to collinearity. Table 5 presents the results, in which the coefficient of "adaptation" remains positive and significant. All control variables are not significant, which demonstrates that the matching process effectively reduces the imbalance in covariates. For propensity score matching, we use the Stata command: *teffects psmatch*. Compared to *psmatch2*, *teffects psmatch* takes into consideration that the propensity scores are estimated rather than known while calculating the standard errors. The resulting average treatment effect on the treated ($\beta=0.129, p=0.04$) and the average treatment effect ($\beta=0.132, p=0.001$) are both positive and significant.

-Insert Table 5 about here-

⁹ It is not appropriate to extend two-stage least squares to a non-linear model like logit. Instead, we estimate the results using *ivprobit* in Stata.

¹⁰ To obtain sufficient matched observations, we need to match based on age in years, rather than age in log.

Due to the data limitations, we approximate the concept of skill improvement using a binary variable. The questionnaire shows that firms either increase, maintain, or decrease the number of skilled workers after introducing the imitative product. The dependent variable “skill improvement” in the main analysis takes the value of one when firms increase the number of their skilled workers, and zero otherwise. To show the robustness of the main analysis, we created a three-categorical variable, “skill improvement 2”. It takes the value of three, two, or one, depending on whether firms increase, maintain, or decrease the number of skilled workers after product imitation. We used this as the dependent variable in the robustness check. We conducted regression analyses using the same set of independent and control variables. Table 6 presents the estimated coefficients.

-Insert Table 6 about here-

In Model 5, we assume an order between the three categories: increasing, maintaining, and decreasing the number of skilled workers. The results of the ordered logistic regression are consistent with the main analysis, which was conducted using binary logistic regression. The coefficient of “adaptation” is positive and significant. The log odds that adapters will attain a higher level of “skill improvement 2” is 0.51 greater compared to reproducers, holding all other remaining variables constant. That is, they are about 1.7 ($e^{0.505}=1.7$) times more likely to move from decreasing to maintaining the number of skilled workers, or from maintaining to increasing the number of skilled workers.

Model 6 presents the estimation of multinomial logistic regression with no assumption of an order between the three categories. The baseline category is the same number of skilled workers after product imitation. The coefficient of “adaptation” is positive and significant when estimating an increase versus the baseline category. The relative log odds of increasing vs. maintaining the number of skilled workers increases by 0.51 when firms imitate by adaptation. That is, the probability ratio of the increasing the number of skilled workers to that of maintaining the number of skilled workers is about 1.7. The coefficient of “adaptation” is not significant when estimating the decrease vs. the maintenance of the number of the skilled workers.

4.3 Search for the potential mechanism

Adaptation initiates the knowledge acquisition process more frequently and requires firms to practice skills such as purposive search, trial-and-error, and problem-solving in order to integrate information from varied sources. We argue that such a mechanism explains why adapters are more likely to improve their skills than reproducers. Previous studies reveal consistent evidence to that effect. Hobday (1995) has suggested the relevance of information from internal R&D and foreign technology suppliers in the Asian Tiger catch-up process. Chen

(2009) has shown how Taiwanese machine tool firms leveraged information from varied sources to climb the technological ladder. The specific requirements of local users forced them to find solutions to meet customers' needs. Exchanging information with local suppliers led to improved product development processes. The likelihood of skill improvement increases when imitators incorporate information from sources other than the target.

If the proposed mechanism is in effect, "adaptation" will have an effect only in the situation where firms need to integrate information from varied sources. We divided the sample into two subsamples based on whether the imitators use information from varied sources. Then, we ran the main regression analysis separately on each subsample. We expect to observe a positive and significant coefficient of "adaptation" in the subsample of firms using information from varied sources to develop their imitative products. This need not be the case for the subsample of firms using only information from the target.

We identified two questions from the survey which can be used to split the sample. The first one asked respondents to indicate their most important sources of information for developing new products. To imitate, information from the target product is essential. Thus, we consider that firms use information from varied sources if they indicate that the most important source of information is from other sources, apart from the existing product. The second question is about whether firms use the internet to gather information and ideas for developing new products. Since the internet is a powerful tool for gathering information from a variety of sources, we consider that the use of the internet provides firms with information from varied sources.

Table 7 presents the regression results. Both models include the same set of controls as the main analysis. The sample size was reduced to 1,072 and 468, respectively, excluding observations with missing values. The results are consistent with our expectations. The coefficient of "adaptation" is positive and only significant for the subsample of firms that use information from varied sources—the most important source is not from the target product or internet use for developing ideas for new products.

-Insert Table 7 about here-

5. Discussion and conclusion

Motivated by the importance of SMEs in developing countries and taking into consideration their financial constraints, this article suggests the possibility of skill improvement via product imitation. We distinguish between kinds of product imitation based on the information inputs during the imitation process. We argue that compared to reproduction, adaptation is more likely to enhance imitators' skills. Due to using information from a

variety of sources, adapters have a greater chance of gaining knowledge and are more likely to practice complex skills such as trial and error and problem-solving. The empirical evidence from SMEs in nine lower-income countries supports this expectation. Our findings are consistent with the development path of some firms from developing countries. For example, due to protection of intellectual property rights (IPR), reproducing a patented drug is infeasible, and thus Ranbaxy Laboratories (an Indian pharmaceutical firm) needs to adapt its production process in order to produce its own generic drugs. Focusing on such adaptation facilitates Ranbaxy Laboratories progression from being a manufacturer of active pharmaceutical ingredients (API) to being one of patent holders (Athreya, Kale, and Ramani 2009). A counter example is Video Brinquedo, an animation video company in Brazil. Video Brinquedo was famous for its ability to reproduce films from Disney and DreamWorks (Luo et al. 2011). Dedicating itself to reproduction did not lend Video Brinquedo sufficient opportunities for skill improvement before it went defunct in 2012.

SMEs in lower-income countries tend to lag behind technologically, but have abundant access to inexpensive, unskilled workers. Many already imitate products, and the easiest way to grow is to continue imitating using whatever cheap labor is available. However, a more sustainable path would be build the capability to innovate through skill improvement. This would help them overcome the decreasing advantages of imitation (Aghion and Howitt 2006; Liao 2020). Thus, our findings that product imitation, and adaptation in particular, facilitates skill improvement has implications for policy. Governments could implement policies that encourage adaptation rather than reproduction, thus encouraging SMEs to benefit from product imitation. For example, a stronger reform of the intellectual property protection regime might help by obliging firms to adapt rather than content themselves with mere imitation. Studies on the progress of India's pharmaceutical industry demonstrate that strengthening IPR regime forces firms to move away from reproducing western patented drugs (Athreya, Kale, and Ramani 2009; Kale and Little 2007). While showing that product imitation could enhance skills, we do not discount the importance of technology adoption and R&D investment. The combination of different policies to encourage adaptation, as well as investment in R&D and technology adoption, would facilitate SMEs reaching sustainable growth.

While highlighting the value of our study, we acknowledge its limitations. Our analyses are based on cross-sectional data, which constrain our ability to deal with endogeneity. We tried our best to theorize a causal direction from adaptation to skill improvement, as well as to provide consistent empirical evidence to support our claim. Although the instrumental variable and matching approaches have yielded favorable results, we acknowledge that we cannot completely remove all potential concerns due to endogeneity. The measurement for

skill improvement used here—whether imitators increase the number of skilled workers after introducing imitative products—is not ideal. Although this measurement captures an important element of the skill improvement process, it does not account for certain situations. While increasing the number of skilled workers, imitators might also increase the number of unskilled workers. Given a net increase in skilled workers, merely hiring the holder of a PhD or a bachelor degree is not the same thing. Without knowing the tasks performed by the additional skilled workers, it is difficult to describe the extent of skill improvement. In addition, skill improvement often takes time, and therefore longitudinal data would be superior to cross-sectional data. To capture the construct of skill improvement fully, detailed information about employee qualifications, such as their years of schooling and professional training, is needed both before and after product imitation. Furthermore, the countries and industries covered by the study might limit the application of the findings. Our analyses relied on publicly available data, and our selection of countries was driven by data availability. We did not randomly select the nine countries included in the sample, and they are not representative of all developing countries. The industries covered are mainly non-high-tech and labor-intensive, which reflects most economic activities in lower-income countries. However, whether the findings can be applied to high-tech industries needs to be discussed.

Future research can build upon the idea that imitation facilitates skill improvement and examine potential contingencies. Imitation involves the transfer of knowledge between the imitator and the firm offering the target product. In this case, factors affecting the likelihood of successful knowledge transfer are likely to condition the skill improvement effect. Possible contingencies include complexity of the target product, willingness to learn, and the degree of similarity between the imitator and the firm offering the target product. How these factors interact with different imitation processes would be interesting to explore as well.

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Table 1 Descriptive statistics

Variable	Description	Overall sample (<i>N</i> = 1,076) ^a				Subsample Firms that adapt an existing product (<i>N</i> = 782)	
		Min.	Max.	Mean	SD	Mean ^b	SD
Skill improvement	Whether the number of skilled workers increased due to introducing the imitative product (yes/no)	0	1	0.45	0.50	0.50***	0.50
Adaptation	Binary variable: one for adaptation and zero for reproduction	0	1	0.73	0.45	1.00	0.00
New process	At least one new or significantly improved process introduced during the survey period (yes/no)	0	1	0.66	0.47	0.68	0.47
Investment intensity	Amount of spending on internal R&D and fixed assets or software for R&D per employee (in 2009 US dollars with log transformation)	0	17.21	3.26	3.56	3.33	3.37
New technology	Whether the imitative product was based on a technology or on industrial design not already used by the firm (yes/no)	0	1	0.52	0.50	0.51	0.50
New knowledge	Whether firms purchased or licensed any patented or non-patented invention or knowledge to develop the imitative product (yes/no)	0	1	0.05	0.23	0.06	0.23
Firm size	Number of employees (in log)	0.69	4.60	2.75	0.79	2.74	0.80
Firm age	Number of years of firm operation (in log)	0	4.67	2.55	0.77	2.57	0.75

*** $p < .001$.

^a The working dataset contains 1,076 imitating firms, excluding observations with missing values.

^b The equality of means between firms reproducing and adapting an existing product is tested using *t* tests. The significance of the *p* value is indicated next to the mean value.

Table 2 Coefficients of correlation

	1	2	3	4	5	6	7	8
1 Skill improvement	1							
2 Adaptation	.16	1						
3 New process	.14	.04	1					
4 Investment intensity	.16	.03	.31	1				
5 New technology	.04	-.03	-.01	.04	1			
6 New knowledge	.06	.02	.09	.09	.02	1		
7 Firm size	.18	-.01	.09	.11	-.00	.08	1	
8 Firm age	.02	.04	.02	.04	.01	-.00	.19	1

N=1,076

Table 3 Main analysis using logistic regression

Dependent variable: Skill improvement	
Model	Coefficient (1)
Independent variable	
Adaptation	0.518** (0.162)
New process	0.481** (0.155)
Investment intensity	0.067** (0.021)
New technology	0.393** (0.138)
New knowledge	0.568+ (0.305)
Firm size	0.361*** (0.091)
Firm age	-0.212* (0.094)
Constant	-2.287*** (0.392)
Country dummy	Yes
Sectoral taxonomy dummy	Yes
Manufacturing dummy	Yes
No. of observations	1,076
LR chi2(18)	183.24***
Pseudo R ²	.124

+ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Standard errors are within parentheses.

Table 4 Probit model with instrumental variable

Dependent variable: skill improvement		
Estimators	Coefficient	
	Maximum likelihood	Two-step
Model	(2)	(3)
Independent variable		
Adaptation	1.898*** (0.421)	2.669* (1.334)
New process	0.116 (0.119)	0.163 (0.139)
Investment intensity	0.017 (0.016)	0.024 (0.019)
New technology	0.162 (0.090)	0.228* (0.104)
New knowledge	0.206 (0.184)	0.290 (0.234)
Firm size	0.196*** (0.058)	0.276*** (0.076)
Firm age	-0.121* (0.053)	-0.170* (0.075)
Constant	-2.244*** (0.220)	-3.156** (1.032)
Country dummy	Yes	Yes
Sectoral taxonomy dummy	Yes	Yes
Manufacturing dummy	Yes	Yes
No. of observations	1,076	1,076
Wald chi2(18)	418.41***	109.82***

* $p < .05$, ** $p < .01$, *** $p < .001$.

Standard errors are within parentheses.

Table 5 Robustness check using coarsened exact matching

Dependent variable: Skill improvement	
Model	Coefficient (4)
Independent variable	
Adaptation	2.706** (0.941)
New process	-0.418 (1.456)
Investment intensity	0.124 (0.167)
New technology	0.228 (0.959)
New knowledge	- -
Firm size	2.962 (1.595)
Firm age	0.502 (0.931)
Constant	-9.384* (3.945)
Country dummy	Yes
Sectoral taxonomy dummy	Yes
Manufacturing dummy	Yes
No. of observations	65
LR chi2(14)	38.57***
Pseudo R ²	.439

* $p < .05$, ** $p < .01$, *** $p < .001$.

Standard errors are within parentheses.

Table 6 Robustness check using ordered and multinomial logistic regression

Dependent variable: Skill improvement 2			
Model	Ordered	Multinomial	
	(5)	(6)	
		Increasing versus baseline ^a	Decreasing versus baseline ^a
Independent variable			
Adaptation	0.505** (0.156)	0.514** (0.163)	-0.102 (0.467)
New process	0.420** (0.149)	0.499** (0.155)	0.577 (0.534)
Investment intensity	0.069*** (0.020)	0.066** (0.021)	-0.014 (0.054)
New technology	0.323* (0.134)	0.420** (0.139)	0.828 (0.497)
New knowledge	0.568 (0.302)	0.571 (0.308)	0.194 (1.085)
Firm size	0.369*** (0.089)	0.350*** (0.091)	-0.258 (0.318)
Firm age	-0.224* (0.091)	-0.205* (0.094)	0.135 (0.320)
Constant	-	-2.274*** (0.394)	-4.490*** (1.305)
Country dummy	Yes	Yes	Yes
Sectoral taxonomy dummy	Yes	Yes	Yes
Manufacturing dummy	Yes	Yes	Yes
No. of observations	1,076		1,076
LR chi2(18)	187.73***		
LR chi2(36)			233.06***
Pseudo R ²	0.111		0.133

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Estimated coefficients are reported. Standard errors are within parentheses.

^a Baseline category maintains the same number of skilled workers after product imitation.

Table 7 Evidence supporting the proposed mechanism

Dependent variable: Skill improvement				
Logit model	(7) Most important information source (N=1,072)		(8) Use the internet to develop new products (N=468)	
	The target product	Not the target product	Yes	No
Independent variable				
Adaptation	0.579 (0.450)	0.510** (0.181)	0.647* (0.281)	-0.388 (0.503)
New process	0.786* (0.401)	0.412* (0.172)	0.264 (0.306)	0.023 (0.451)
Investment intensity	0.168** (0.060)	0.055* (0.023)	0.033 (0.033)	0.136* (0.063)
New technology	0.436 (0.360)	0.448** (0.155)	0.033 (0.256)	0.793 (0.421)
New knowledge	1.565 (1.342)	0.563 (0.319)	0.878 (0.457)	0.141 (1.076)
Firm size	0.442* (0.219)	0.341*** (0.101)	0.107 (0.161)	0.268 (0.280)
Firm age	-0.143 (0.245)	-0.189 (0.105)	-0.061 (0.180)	-0.035 (0.258)
Constant	-3.408** (1.049)	-2.227*** (0.437)	-1.310 (0.759)	-1.135 (1.226)
Country dummy	Yes	Yes	Yes	Yes
Sectoral taxonomy dummy	Yes	Yes	Yes	Yes
Manufacturing dummy	Yes	Yes	Yes	Yes
No. of observations	195	877	301	167
LR chi2(17) ^a	53.12***			
LR chi2(18)		145.7***	33.02*	62.27***
Pseudo R ²	0.197	0.121	0.079	0.276

* $p < .05$, ** $p < .01$, *** $p < .001$.

Estimated coefficients are reported. Standard errors are within parentheses.

^a Only one firm from Pakistan considers the target product as the most important source, so the country dummy for Pakistan is dropped from the regression.