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SMEs' in-house R&D, outsourced R&D or both: The supply-chain FDI linkages and technology transfer

Quang-Thanh Ngo[a,b*]

[a]*Center for Economic and Financial Research (CEFR), University of Economics and Law (UEL), Ho Chi Minh City 71309, Vietnam*
[b]*University of Economics and Law (UEL), Vietnam National University Ho Chi Minh City (VNU-HCM), Ho Chi Minh City 71309, Vietnam*

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A B S T R A C T

This article aims to analyze factors affecting the probability that a firm choose to diversify its investment in R&D. Recently, industry policy in developing countries tends to spur SMEs in terms of Research & Development (R&D), considering them as a main driver of innovation and growth. Departing from an extensive sample of the Vietnam Technology and Competitiveness Survey in combination with the Vietnam Enterprise Survey in 2011-2013, we try to determine: (1) those factors that cause young firms to invest in in-house R&D or in outsourced R&D or both (in-house R&D and in outsourced R&D), and (2) what is the difference in the impact of those factors when taking supply-chain foreign direct investment (FDI) linkage, and technology transfer into account. The analysis results highlight the importance of direct linkages, technology transfer between FDI firms and young SMEs, economic obstacles, and the interactions between them that cause SMEs to conduct R&D strategies in the supply chain (obtained through direct transfer of technology between linked firms). Concerning policies must be aware that incentives along supply-chain may better reach the R&D outcomes for SMEs. Important equally, policy-makers must consider a broader range of economic and financial constraint that may influence R&D behavior, apart from export orientation, competitiveness, and market power.

1. Introduction

In the past decade, we have also observed an emerge of open innovation model, where firms complement and supplement their own technological resources with those of other firms (Chesbrough, 2003; Ngo et al., 2020). Buxton (2008), and Clark and Rhoads (2009) indicate that in-house basic research is no longer economically warranted and that the role of the corporate lab needs to be mostly that of a coordinator and integrator of internal and external knowledge. However, there exists no scientific empirical research to analyze the diversification of R&D activities in small firms. The question of what factors affect various R&D decisions of a firm in a world of interdependencies has attracted a series of papers. Previous studies include: Audretsch, Segarra, and Teruel (2014) who analyze initial innovation capacity and cooperation in R&D; Tingvall and Poldahl (2012) who examine relationship-specific interactions between buyer and seller; Ejermo and Bergman (2014) who analyze foreign and domestic sales impact; Guzzini and Iacobucci (2014) who evaluate the business group impact; Czarnitzki and Hottenrott (2011) who test financial constraints; Romero-Jordan, Delgado-Rodríguez, Alvarez-Ayuso, and de Lucas-Santos (2014) who assess the impact of tax credits and public grants; Müller and Zimmermann (2009) who investigate the importance of equity finance. Hence, it seems clear that relationship-specific investments may be related to a wide range of issues. However, given the close relation between FDI and technology transfer, it is surprising that no one has yet analyzed the influence of FDI linkages and technology transfer in the context of SMEs; hence, the paper aims to fill this gap. According to Vietnam Enterprise Survey (VES) in 2013 (CIEM & University of Copenhagen, 2013), approximately 514 (6.4%) of the 8,010 firms in the sample invested in some form of R&D in 2012. Looking at the type of

* Corresponding author
E-mail address: thanhnq@uel.edu.vn (Q.-T. Ngo)

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research undertaken by firms, 53% of this research expenditure was focused on developing technology that is new to the market the firm operates in, rather than 'frontier research' which represents only 4% of research expenditure (from a sample of 504 firms). The remaining 43% was used to research development into technologies that are new to the enterprise. Although R&D on 'frontier research' is low, examining the determinants of undertaking research activity is still important in order to inform appropriate industrial policy for Vietnam with regard to R&D investment. Consequently, using the Vietnam Technology and Competitiveness Survey in combination with the Vietnam Enterprise Survey in 2011-2013, the purpose of this article is to analyze the impacts of FDI linkages and technology transfer, that might cause SMEs (those have employees from 10 to less than 250) to diversify its investment in R&D. We claim that there are conditions, and incentives that may cause such SMEs to choose to invest in in-house R&D (in-house R&D SMEs, IRD-SMEs), outsourced R&D (outsourced R&D SMEs, ORD-SMEs) or both (in-house and outsourced R&D SMEs, RD-SMEs).

The structure of the article is the following. The next section presents the literature review with particular emphasis on the motivative that SMEs may encounter when deciding whether or not to invest in in-house R&D or outsourced R&D or both types of R&D. Section 3 shows the main characteristics of the dataset and the econometric methods. Section 4 discusses the results. Finally, we present our main conclusions and implication in section 5.

2. Literature review

2.1. Motivation to conduct R&D

General results on the determinants of R&D are discovered by various studies. Lai, Lin, and Lin (2015) focus on specific internal strategic resources that explore the firms' R&D investment behavior and show that physical resources such as company size and intangible resources such as goodwill and patents have the impact on the R&D investment decisions. Tingvall and Poldahl (2012) analyze not only how international and domestic (inter- and intra-industry) technology spillovers affect firm's R&D but also how relationship-specific interactions between buyer and seller influence such spillovers. They find that international technology spillovers to be larger and more significant than domestic inter- and intra-industry spillovers. Moreover, relationship-specific interactions between seller and buyer enhance technology spillovers in general and international spillovers in particular. In terms of competition, less concentrated industries, industries with fewer sunk costs and in the early stages of the life cycle favor the appearance of small innovative entrants (Acs & Audretsch, 1987; Utterback, 1994; Malerba, 2004). Recently, Aghion, Bloom, Blundell, Griffith, and Howitt (2005) integrate these two contrasting forces and remark on the presence of an inverted U-shape relationship between market competition and innovation. The perhaps most obvious and well-studied driver of R&D is the size. Decades of empirical research on the relationship between firm size and R&D have established a consensus view of a R&D elasticity with respect to firm size close to unity. In the empirical literature on the determinants of firm R&D, the capital intensity of the firm is also important. This is not surprising because technological innovations are typically embodied in new machinery (Stoneman, 1995). For example, DeLong and Summers (1992) argue that countries with high capital investment rates tend to be those with high productivity growth, and Aghion and Howitt (1999) demonstrate how a positive correlation between innovation and capital intensity can be established.

2.2. In-house and outsourcing R&D

According to Schumpeter (1934, 1980), monopoly rents and profits are crucial for financing firm's R&D, and several studies have followed that theory (Arrow, 1962; Dasgupta & Stiglitz, 1980). However, over the past two decades, it is observed that there is a coexistence of two models: (1) the closed innovation model, where firms generate, develop and commercialize their own ideas, and (2) the open innovation model, where firms complement and supplement their own technological resources with those of other firms and rely increasingly on external sources of knowledge (Bönte (2003); Chesbrough (2003)). Technology alliances enable firms to expand to such an open innovation model (Hagedoorn, 2002; Dittrich & Duysters, 2007)). Sole reliance on in-house R&D has apparently become unsatisfactory given the growing complexity and speed of technological developments (Granstrand, Bohlin, Oskarsson, & Sjöberg, 1992); Narula, 2001). However, relative advantages and disadvantages between in- house R&D and outsourcing R&D are controversial in terms of the ultimate purpose of firm's productivity. Common knowledge says that due to economies of specialization and knowledge spillovers (Bönte, 2003), outsourced R&D obtains a bigger productivity gain. In addition, outsourced R&D stimulus spillovers from the outside to the firm's absorption capacity, and thus improve a firm's innovation capabilities (Eisenhardt & Schoonhoven, 1996). However, other authors suggest that in-house R&D is superiors than outsourced R&D in terms of productivity. The first reason is the firm's absorption capacity (Howells, 2006; Grimpe & Kaiser, 2010). The second is relates to the transaction costs incurred in setting up and managing the collaborative agreements which may impede the outsourced R&D. The third is the costs of collaborative activities cancel out the positive impact of innovation collaboration in the short term, leading to a negative effect on firm profitability (Arvanitis & Loukis, 2013).

We argue that the factors behind in-house R&D and outsourced R&D indeed determine the level of firm's productivity. Thus, it is an interesting question that which drivers lead a firm to choose in-house R&D, outsourced R&D or both.

3. Data and methods

3.1. Data

The data are from five annual Vietnam Technology and Competitiveness Surveys which gathered detailed information on supply chain linkages, firms' R&D, and technology transfers for a nationally representative sample of over 4000 manufacturing enterprises in 2011-2013. The sample is a subset of manufacturing firms covered by the Vietnam Enterprise Survey (VES) administered annually by the General Statistics Office. The VES gathers balance sheet and other information on the activities of firms. We match TCS data with information on firm activities and financial accounts gathered in VES. With regard to R&D, the questionnaire asks the question: "Does your enterprise undertake research and development (R&D) activities in order to develop new technologies?". Anh then if the answer is yes, the next question is: "Where are these R&D activities performed?". Answers are one of these: (1) In-house, (2) Out of house, and (3) Both. Table 1 shows the distribution of our sample. Our database has 4,018 observations in three-year panel (4,018 SMEs in each). The percentage of IRD-SMEs represents around 6.6% of our sample at the beginning of the period of observation, while this value reduces to around 3.4% at the end of the period of observation. With respect to ORD-SMEs, the starting value is around 0.92%, and at the end of our period of observation it is equal 0.47%. With respect to firms with both in-house and outsourced R&D (RD-SMEs), the starting value is around 3.01%, and at the end of our period of observation it is equal 1.72%.

Table 1
Distribution of firms over time, SMEs

Year	IRD-SMEs: N, (%)	ORD-SMEs: N, (%)	RD-SMEs: N, (%)	NRD-SMEs: N, (%)	Sample: N, (%)
2011	289 (6.61)	45 (1.03)	135 (3.09)	3,902 (89.27)	4,371 (100.00)
2012	253 (5.75)	35 (0.89)	129 (2.93)	3,982 (90.52)	4,399 (100.00)
2013	177 (3.88)	23 (0.50)	84 (1.84)	4,273 (93.77)	4,557 (100.00)
Total	719 (5.4)	103 (0.77)	348 (2.61)	12,157 (91.22)	13,327 (100.0)

Note: IRD-SMEs: in-house R&D SMEs; ORD-SMEs: outsourced R&D SMEs; RD-SMEs: R&D SMEs; NRD-SMEs: non-R&D SMEs. N: number of observations. Source: Author's calculation from TCS and VES.

Table 2 shows the main characteristics of our four groups of firms: IRD-SMEs, ORD-SMEs, RD-SMEs and non-R&D SMEs (Non-R&D SMEs, NRD-SMEs). We observe differences among IRD-SMEs, ORD-SMEs, RD-SMEs and their counterparts in profiles. Regarding to firm characteristics, first, IRD-SMEs, ORD-SMEs, and RD-SMEs have higher size of capital (both total assets and equity in absolute terms) than NRD-SMEs, while the mean size of NRD-SMEs in terms of labor has the lowest value regardless of whether we consider the number of employees or volumes of total assets and equity. Second, with respect to the sale volumes, RD-SMEs have higher in absolute terms than both NRD-SMEs and other firms. Third, with respect to the age, IRD-SMEs, ORD-SMEs, and RD-SMEs are older than NRD-SMEs. Fourth, with respect to the openness to international trade, NRD-SMEs is more internationally tradable in terms of both exports and imports than IRD-SMEs, ORD-SMEs, and RD-SMEs.

Table 2
Descriptive analysis, SMEs

Descriptive statistic	IRD-SMEs	ORD-SMEs	RD-SMEs	NRD-SMEs	Average
Sales (mill. VND)	68551.74	69456.68	78933.77	44860.61	47218.59
Employees (persons)	86.29	76.59	85.57	56.4	58.93
Age (years)	10.9	11.1	10.8	10.0	10.1
Assets (mill. VND)	60774.58	64423.45	83287.1	34251.45	37196.02
Equity (mill. VND)	21109.44	22849.25	25373.12	11959.17	12887.27
Firm exports (%)	0.81	0.78	0.81	0.86	0.85
Firm import (%)	0.86	0.78	0.86	0.87	0.87
Number of observations					

Note: Mean and standard deviation in brackets; IRD-SMEs: in-house R&D SMEs; ORD-SMEs: outsourced R&D SMEs; RD-SMEs: R&D SMEs; NRD-SMEs: non-R&D SMEs. Source: Author's calculation from TCS and VES.

Regarding constraints delaying the enterprise's performance, as shown in Fig. 2, firstly, in general, larger percentages of RD-SMEs state that they suffer all seven types of the constraints in comparison with NRD-SMEs. Secondly, larger percentages of IRD-SMEs state that they suffer the constraints in basic infrastructure, transport infrastructure, communication infrastructure, the labor force, technological know-how and technologies than ORD-SMEs do. However, larger percentages of ORD-SMEs state that they suffer the constraints in financing than IRD-SMEs do.

Thirdly, larger percentages of ORD-SMEs state that they suffer constraints in basic infrastructure, financing, technological know-how than NRD-SMEs do. However, larger percentages of NRD-SMEs state that they suffer the constraints in transport infrastructure, communication infrastructure than ORD-SMEs do.

IRD-SMEs, ORD-SMEs, and RD-SMEs report fewer competitors at the provincial level than NRD-SMEs do, as shown in Figure 3. However, IRD-SMEs, ORD-SMEs also report more competitors at the national level than NRD-SMEs do. This indicates that IRD-SMEs, ORD-SMEs tend to be more expansive in the competitive national market. NRD-SMEs face least competitors at the international level than any IRD-SMEs, ORD-SMEs, and RD-SMEs does.

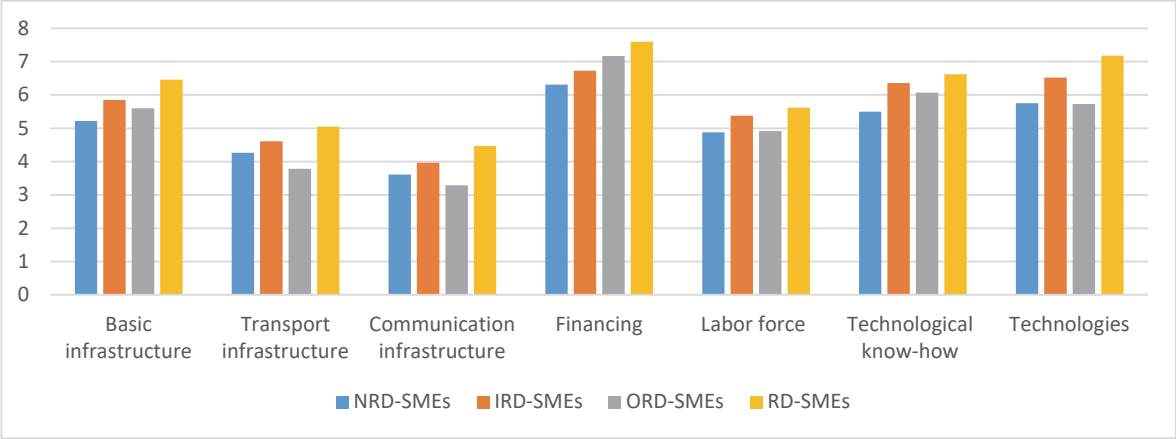

Fig. 2. Constraints on RD-SMEs' economic performance; average points over 2011–2013. Note: Seven types of constraints: (1) basic infrastructure (electricity, energy, land), (2) transport infrastructure (roads, airports), (3) communication infrastructure, (4) financing (credits, foreign capital), (5) labor force (number of laborers), (6) technological know-how (skilled labor), and (7) technologies (machinery, equipment). The level of constraints is measured as average points of each constraint (range from 0 to 10). Source: Authors' calculation from TCS.

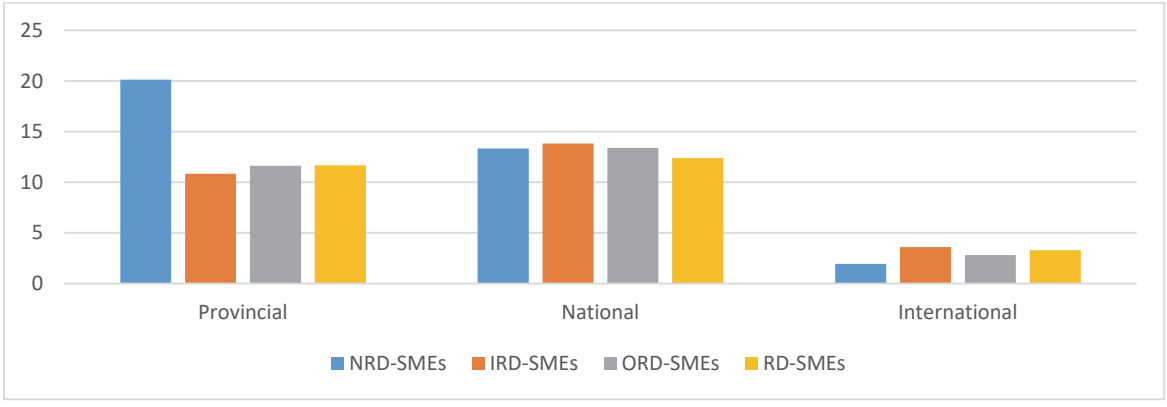

Fig. 3. Average number of competitors by RD-SMEs and NRD-SMEs, 2011–2013. Source: Authors' calculation from TCS

Furthermore, larger percentages of IRD-SMEs, ORD-SMEs, and RD-SMEs state that they face competition in the main field of activity than NRD-SMEs do, as shown in Fig. 4. It is noted that a larger percentage of NRD-SMEs status are "price taker" firms than RD-SMEs do, while obviously, we observe a higher percentage of "significant autonomy in setting prices" for some RD-SMEs, namely: IRD-SMEs, ORD-SMEs.

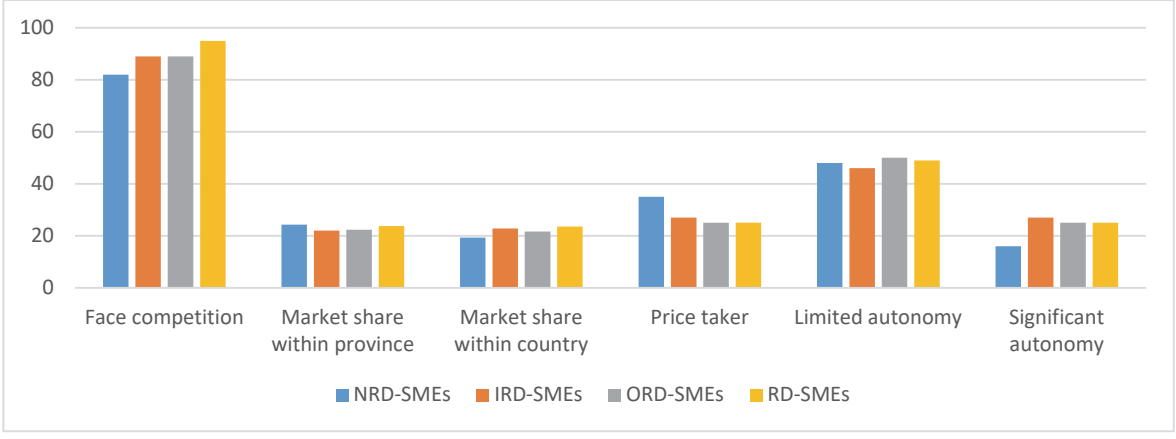

Fig. 4. Competition and firms' market power by RD-SMEs and NRD-SMEs; average percentage over 2011–2013. Source: Authors' calculation from TCS.

To summarize, we find that RD-SMEs and NRD-SMEs differ substantially in terms of size of labor, age, physical capital intensity, sales volumes (growth ability), and openness to international trade. These attributes capture a firm's capability to conduct R&D. Second, RD-SMEs and NRD-SMEs face different constraints on their economic performance. Third, RD-SMEs and NRD-SMEs face different level of competition. In the following, we will present an econometric method in which the differences in R&D behavior are linked to the differences in constraints on their economic performance along the supply chain linkages and technology transfer.

3.2. Methods

The different R&D strategies considered are in-house R&D, outsourced R&D, or both. We are particularly interested in FDI linkages and technology transfers. This is achieved through the estimation of Eq. (1):

$$y_{it} = \begin{cases} 1 \ if \ y_{it}^{*} = f\begin{pmatrix} X_{it}\beta_1 + Z_{it}\delta_1 + \gamma_{11}FDIDomSup_{it} + \gamma_{12}FDIDomCus_{it} + \\ +\gamma_{13}FDIDomSupTech_{it} + \gamma_{14}FDIDonCusTech_{it} + u_{it} \end{pmatrix} > 0 \\ 0 \ otherwise \end{cases} \quad (1)$$

The y^{*}_{it} is the latent dependent variable, X_{it} are the determinants of the decision to conduct a particular R&D choice, Z_{it} is a matrix of time-varying firm specific control variables, β_1, δ_1, γ_{11}, γ_{12}, γ_{13}, γ_{14} corresponds to the vector of coefficients to be estimated and u_{1it} is the error term which follows $N(0, \sigma^2)$. The y_{it} may be observed only when y^{*}_{it} is equal to 1. Equation (1) depends on the following set of explanatory variables (X_{it}): *Size* (sales lagged one period), *Age* (years of operation), *ShareExp* (export share in sales), *FDIDomSup* (firm having relationship with FDI domestic suppliers), *FDIDomCus* (firm having relationship with FDI domestic customers), *FDIDomSupTech* (Technological transfer with FDI domestic suppliers), *FDIDonCusTech* (Technological transfer with FDI domestic customers), *BInfrasT* (difficulties in terms of basic infrastructure such as electricity, energy, land), *TranInfrasT* (difficulties in terms of transport infrastructure such as roads, airports), *ComInfrasT* (difficulties in terms of communication infrastructure), *FinT* (difficulties in terms of financial constraints such as credits, foreign capital), *LabornbT* (difficulties in terms of the number of the labor force), *KnowhowT* (difficulties in terms of technological know-how, namely skilled labor), and *TechT* (difficulties in terms of technologies such as machinery, equipment), *MarketShareP* (market share at province level), *MarketShareC* (market share at country level), *ComP* (competition at province level), and *ComC* (competition at country level).

Table 2
Variables in the model of R&D choices

Variable	Description	IRD-SMEs (N= 719)		ORD-SMEs (N= 103)		RD-SMEs (N= 249)	
		Mean	SD	Mean	SD	Mean	SD
Dependent variable							
R&D choices	Firm conducting a particular R&D (Yes=1; No=0)	0.61	0.49	0.09	0.28	0.30	0.46
Explanatory variable							
Size	ln(sales), lagged one period	9.74	1.71	9.93	1.43	9.97	1.63
Age	ln(age), lagged one period	2.25	0.50	2.32	0.43	2.24	0.50
ShareExp	Export share in sales (%)	11.74	28.4	19.41	36.86	7.51	22.29
FDI linkage							
FDIDomSup	Relationship with FDI domestic suppliers (Yes=1; No=0)	0.11	0.31	0.11	0.31	0.14	0.34
FDIDonCus	Relationship with FDI domestic customers (Yes=1; No=0)	0.18	0.38	0.14	0.34	0.24	0.43
FDI Technology transfer							
FDIDomSupTech	Technological transfer with FDI domestic suppliers (Yes=1; No=0)	0.03	0.18	0.05	0.22	0.06	0.24
FDIDonCusTech	Technological transfer with FDI domestic customers (Yes=1; No=0)	0.03	0.16	0.05	0.22	0.09	0.28
Constraints: Level of difficulties							
BInfrasT	Basic infrastructure	5.85	3.67	5.60	3.83	6.47	3.49
TranInfrasT	Transport infrastructure	4.61	3.50	3.78	3.43	5.05	3.56
ComInfrasT	Communication infrastructure	3.97	3.28	3.29	3.26	4.48	3.45
FinT	Financial constraints	6.73	3.4	7.17	3.29	7.60	3.00
LabornbT	Number of labor force	5.38	3.38	4.92	3.53	5.62	3.32
KnowhowT	Technology know-how	6.36	3.25	6.07	3.35	6.62	3.04
TechT	Technologies	6.52	3.43	5.73	3.74	7.18	3.05
Market share							
MarketShareP	the province level (%)	22.00	28.78	22.34	28.06	23.83	28.66
MarketShareC	the country level (%)	22.84	28.28	21.64	26.77	23.65	27.12
MarketShareP2	the province level (%), squared	1311.20	2551.27	1278.98	2491.99	1386.90	2575.53
MarketShareC2	the country level (%), squared	1320.42	2479.21	1177.69	2231.70	1292.58	2281.40
Competition: Number of competitors							
ComP	the province level	10.84	26.20	11.63	22.47	11.66	27.17
ComC	the country level	13.82	47.45	13.40	34.78	12.37	31.50
ComP2	the province level, squared	803.22	7251.24	635.50	2483.34	872.17	7974.35
ComC2	the country level, squared	2439.68	23495.91	1377.13	9043.94	1142.65	7850.38

Note: Level of difficulties that delay or obstruct the realization of technology in terms of (0 = does not apply, 1 = slightly important, 10 = very important). Number of observations: 13,327 obs. Source: Author's suggestion

Firm size: Schumpeter's work (1934, 1950) are known as the two conflicting "Schumpeterian hypotheses" (Breschi et al., 2000), which argue that both large and small firms have advantages by themselves when it comes to the implementation of innovation. Large firm advantages include (i) scale economies in R&D, (ii) complementarities between R&D and other activities and (iii) fewer financial constraints due to capital market imperfections (Cohen 2010; Cohen and Klepper 1996a). Small firms have an advantage from their larger natural flexibility in doing R&D (Nelson and Winter 1982; Tidd et al. 2005; Cohen 2010). Relevant empirical results also suggest that R&D expenditures will increase when sales and the number of employees increase (Park, Jaeun, & Kim, 2010; Tsai & Wang, 2004; Galende and Suarez (1999)).

Financial resources: Bhagat and Welch (1995) find that R&D and the previous year's asset-liability ratio have significant and positive correlations. Investing in R&D activities requires capital resources (Kim & Park, 2012; Kim et al., 2008). Profitability as a source of long-term financing (Coad & Rao, 2010; Lev & Sougiannis, 1996) increases the probability to invest in R&D.

Human resources: If the human resources value of an enterprise is higher, the technological sensitivity and knowledge spillover effect can promote the absorption of information during the R&D process (Galende & Suarez, 1999). The research findings of Fleming (2001) also suggest that an enterprise's technical staff that have knowledge of technological fields can increase the opportunity of integrating knowledge to create new technology and development of R&D activities. Such human resources indicate that the integration of skills and knowledge in an organization can have a positive impact on the R&D activities of the enterprise (Coad & Rao, 2010; Fleming, 2001).

Business resources such as an enterprise's export activities: Competition in international markets is fiercer than that in the domestic market, and that fierceness in competition is inductive to R&D. Wakelin (1998) found that companies with investments in R&D have a higher level of exports than companies without investments in R&D. Relevant empirical results also show that an enterprise's export activities and expenditure in R&D have a positive correlation (Park et al., 2010; Tomiura, 2007).

Recently, Tingvall and Poldahl (2012) analyzed the role played by domestic and international trade as a vehicle for technology (R&D) spillovers and their impact on firm R&D. As some researchers (Geroski (1990), Cohen and Levinthal (1989)) have noted, spillovers do not come for free, instead, the absorption of outside technology requires efforts (investments in the absorptive capacity). It is therefore plausible to assume that specific buyer-seller interactions work as oil in the transmission of technology spillovers. We further examine the extent to which the economic constraints used in Eq. (1) are related to direct linkage between foreign and domestic firms and technology transfers as well. To test this, we examine the impact of the interaction between economic constraints and being directly linked with foreign firms and technology transfers along the supply chain. The models we estimate is given in Eq. (2).

$$y_{it} = \begin{cases} 1 \;\; if \; y_{it}^{*} = f \left(\begin{array}{c} X_{it}\beta_1 + Z_{it}\delta_1 + \gamma_{11} FDIDomSup_{it} \; + \gamma_{12} FDIDomCus_{it} + \\ +\gamma_{13} FDIDomSupTech_{it} \; + \gamma_{14} FDIDonCusTech_{it} + \\ +\lambda_{11} Z_{it}.FDIDomSup_{it} \quad + \lambda_{12} Z_{it}.FDIDomCus_{it} + \\ +\lambda_{13} Z_{it}.FDIDomSupTech_{it} \quad + \lambda_{14} Z_{it}.FDIDonCusTech_{it} + \\ + u_{it} \end{array} \right) > 0 \\ 0 \; otherwise \end{cases} \tag{2}$$

4. Empirical analysis

The overall aim of our analysis is to determine the extent to which a particular R&D choice by firms is related to economic constraints, FDI linkages, and FDI technology transfer, considering both direct and indirect effects. We begin by estimating the basic specification for economic constraints, FDI linkages, and FDI technology transfer given in Eq. (1). Results are presented in Table 4. We find that a firm with FDI domestic customers resulted in technological transfer is more likely to conduct R&D (*vertical R&D spillovers through backward linkages*) as suggested in the literature of innovation. However, we find no significant effect for the firm only having a linkage with FDI domestic customers. We also find that a firm with FDI domestic suppliers is more likely to carry out in-house R&D and both in-house and outsources R&D at the same time. A firm with FDI domestic suppliers resulted in technology transfer is more likely to implement R&D (*vertical R&D spillovers through forward linkages)*. With respect to firm characteristics, our principal results are the following. First of all, firm size shows significant positive coefficients in all models of R&D, which is in line with study of Vishwasrao and Bosshardt (2001), Scherer (1965), Kamien and Schwartz (1975), Katz and Shapiro (1987), Loury (1979), Fudenberg and Tirole (1985), and Chang and Robin (2006). We find no significant influence of firm age in all of three models. With respect to the export orientation of the firm, we observe interesting differences between the probability of conducting an outsourced R&D or both. While it shows a significantly negative impact for both types of R&D, this impact is significantly positive for the probability of being an outsourced R&D. Our results confirm that firms which export do not tend to conduct an in-house R&D or both types of R&D, but are more likely to outsource. The explanation may be due to the heavy costs of conducting R&D by themselves or the need to meet the customers' quality requirements.

With respect to the market power of the firm in terms of the market shares at the national level, we also observe a significantly inversed U-shaped pattern for the probability of conducting in-house R&D or both types of R&D. Our results indicate that the volumes of the market power likely increase the probability of conducting in-house R&D or both types of R&D at the first stage of development, and decrease the probability of conducting in-house R&D or both types of R&D at the later stage of development. This is in line to what Scherer (1965) found that innovation is spurred by competition but that too much competition does not allow profits to pay for the technology. An explanation may be when firm with more market power, it may have less competition incentive to invest more in R&D, even it can have more financial resource to do so. Similar patterns are found with respect to the domestic competitiveness of the firm proxied by the number of nation-level competitors. The impact co competition follows an inversed U-shaped pattern for the probability of conducting in-house R&D or both types of R&D. The finding of significant competition role is in line with studies by Scherer (1965), Kamien and Schwartz (1975), Katz and Shapiro (1987), Loury (1979) and Fudenberg and Tirole (1985). The significantly positive impact has been found on the barriers of basic infrastructure on the probability of conducting in-house R&D, financial constraints on conducting outsourced R&D or both types of R&D, technological know-how on conducting in-house R&D, and technologies on conducting both types of R&D. These look reasonable (Ghassemi et al., 2018).

Table 4

Constraints, FDI linkage and technology transfer: total effects (marginal effect), 2011-2013

VARIABLES	In-house	Outsourced	Both R&D
Sales lagged one period (log)	0.102***	0.104**	0.142***
Age (Log form)	0.0329	0.162	-0.0795
Export share in sales (%)	0.000390	0.00463**	-0.00459**
Having FDI domestic customers	0.0455	-0.128	0.174
FDI domestic customers with technological transfer	-0.223	0.478	0.954***
Having FDI domestic suppliers	0.341***	0.187	0.417***
FDI domestic suppliers with technological transfer	0.438**	0.590	0.540**
Market share (province)	-0.0156***	-0.00753	-0.00998**
Market share (country)	0.0147***	0.00617	0.0139***
Market share (province), squared	0.000129***	5.14e-05	7.76e-05
Market share (country), squared	-0.000116***	-3.86e-05	-0.000129**
Competitors (province)	-0.00648***	-0.00334	-0.00374**
Competitors (nation)	0.00256*	0.00438	0.00442*
Competitors (province), squared	3.85e-06***	9.08e-07	2.16e-06
Competitors (nation), squared	-2.76e-06	-1.06e-05	-1.11e-05
Basic infrastructure	0.0249**	0.0283	0.0198
Transport infrastructure	-0.00758	-0.0349	-0.0225
Communication infrastructure	-0.0130	-0.00536	0.0248
Financial constraints	-0.00680	0.0471**	0.0447***
Number of labor force	-0.00860	-0.0304	-0.0208
Technology know-how	0.0379***	0.0380	0.00843
Technologies	0.0134	-0.0336	0.0544***
Observations	13,303	13,303	13,303
Number of firms	4,582	4,582	4,582
Log Likelihood	-2417	-536	-1367
Rho	0.641	0.607	0.633
Likelihood-ratio test of rho=0	528.2	71.81	245.8

Note: Each model is estimated using random effects. * p < 0.10, ** * p < 0.05, *** p < 0.01. 0.0: less than 0.000001. Source: Authors' estimation from VES-TCS

We then continue look at the indirect effects by estimating the interaction specification for economic constraints, FDI linkages, and FDI technology transfer given in Eq. (3). Results are presented in Table 5. First, for firms with FDI domestic customers, the significantly negative impact has been found on the barriers of communication infrastructure on the probability of conducting an in-house R&D. However, the significantly positive impact has been found on the barriers of transport infrastructure on the probability of conducting an in-house R&D. Constraint in financing on the other hand prevents firms to engage into an outsourced R&D. Among firms with FDI domestic customers resulted in technological transfer, the significantly negative impact has been found on the barriers of basic infrastructure on the probability of carrying out an outsourced R&D (*vertical R&D spillovers through backward linkages)*.

Second, among firms with FDI domestic suppliers, the significantly positive impact has been found on the barriers of transport infrastructure on the probability of carrying out an outsourced R&D. In addition, constraint in technology know-how on the other hand prevents firms to exercise in-house R&D. Among firms with FDI domestic suppliers resulted in technological transfer, the significantly positive impact has been found on the barriers of transport infrastructure, and labor force on the probability of conducting an in-house R&D (*vertical R&D spillovers through forward linkages)*. Besides, among firms with FDI domestic suppliers resulted in technological transfer, the significantly negative impact has been found on the barriers of financing on the probability of conducting both types of R&D

Table 5

Constraints and FDI linkage and technology transfer: Indirect effects (marginal effect), 2011-2013

VARIABLES	In-house	Outsourced	Both R&D
Sales lagged one period (log)	0.0807***	0.0847**	0.1180***
Age (Log form)	0.0673	0.1770	-0.0268
Export share in sales (%)	0.0003	0.0048***	-0.0043***
Having FDI domestic customers	0.2310	-0.1040	0.4750*
FDI domestic customers with technological transfer	-0.1890	0.5700	0.1130
Having FDI domestic suppliers	0.3110	0.2580	-0.3010
FDI domestic suppliers with technological transfer	0.1610	0.9180	1.485**
Market share (province)	-0.0145***	-0.00784	-0.00862**
Market share (country)	0.0131***	0.0076	0.0139***
Market share (province), squared	0.0001***	4.85e-05	6.49e-05
Market share (country), squared	-0.0001***	-5.60e-05	-0.0001**
Competitors (province)	-0.0060***	-0.0033	-0.0035**
Competitors (nation)	0.0021*	0.0047	0.0033*
Competitors (province), squared	3.52e-06***	1.39e-06	2.14e-06
Competitors (nation), squared	-2.16e-06	-1.16e-05	-8.60e-06
Basic infrastructure	0.0211**	0.0360*	0.0149
Transport infrastructure	-0.0190	-0.0601**	-0.0208
Communication infrastructure	-0.0011	0.0115	0.0136
Financial constraints	-0.0007	0.0552**	0.0472***
Number of labor force	-0.0134	-0.0343	-0.0154
Technology know-how	0.0509***	0.0606**	0.0151
Technologies	0.0050	-0.0524**	0.0386**
Interactions with FDI domestic customers			
Basic infrastructure	-0.0600*	0.1130	0.0171
Transport infrastructure	0.0858**	0.0870	-0.0250
Communication infrastructure	-0.0280	-0.0282	0.0520
Financial constraints	-0.0369	-0.148**	-0.0269
Number of labor force	0.0080	-0.0370	-0.0259
Technology know-how	-0.0180	-0.0380	-0.0519
Technologies	0.0223	0.0467	0.0194
Interactions with FDI domestic customers resulted in technological transfer (vertical R&D spillovers through backward linkages)			
Basic infrastructure	0.0770	-0.3060*	-0.0255
Transport infrastructure	-0.1280	-0.0415	0.0319
Communication infrastructure	0.0526	0.0895	0.0151
Financial constraints	0.0768	0.0709	0.0139
Number of labor force	0.0354	0.1010	0.1020
Technology know-how	-0.0837	-0.1070	-0.0223
Technologies	-0.0205	0.180	0.0105
Interactions with FDI domestic suppliers			
Basic infrastructure	0.0016	-0.1340	0.0449
Transport infrastructure	0.0104	0.2080**	0.0806
Communication infrastructure	-0.0512	-0.1360	-0.0518
Financial constraints	0.0167	0.0043	0.0192
Number of labor force	0.0745	0.0582	-0.0434
Technology know-how	-0.1110**	-0.1130	-0.0183
Technologies	0.0392	0.0648	0.0600
Interactions with FDI domestic suppliers resulted in technological transfer (vertical R&D spillovers through forward linkages)			
Basic infrastructure	-0.0021	-0.0526	-0.0735
Transport infrastructure	0.2590***	-0.0386	-0.0021
Communication infrastructure	-0.1650*	0.0089	-0.0900
Financial constraints	-0.0382	0.128	-0.1390*
Number of labor force	0.1610*	0.0067	0.0647
Technology know-how	-0.0308	-0.1030	0.1600
Technologies	-0.1360	-0.0258	-0.1040
Observations	13,303	13,303	13,303
Number of firms	3,285	3,285	3,285
Log Likelihood	-2474	-527.8	-1390
Rho	0.522	0.545	0.513
Likelihood-ratio test of rho=0	377.2	57.78	171.7

Note: Each model is estimated using random effects. Time varying firm-level control variables included in Table 3 are also included here but are not presented for ease of presentation. They are available on request. * p < 0.10, ** * p < 0.05, *** p < 0.01. Source: Authors' estimation from VES-TCS

5. Conclusions and implication

SMEs' R&D is crucial to increase long-term productivity. However, the question of what factors affect various R&D decisions of a firm in a world of interdependencies has attracted a series of papers. On top of that, given the close relation between FDI and technology spillovers, it is surprising that no one has yet analyzed the influence of FDI linkages and technology transfer in the context of SMEs; hence, the paper aims to fill this gap. The purpose of this article is to analyze the impacts of FDI linkages and technology transfer, that might cause SMEs (those have employees from 10 to less than 250) to diversify its investment in R&D. We claim that there are conditions, and incentives that may cause such SMEs to choose to invest in in-house R&D, outsourced R&D or both (in-house and outsourced R&D). Supported by the Vietnam

Technology and Competitiveness Survey in combination with the Vietnam Enterprise Survey in 2011-2013, we establish a dataset consisted of over 4300 Vietnamese SMEs in the period 2011–2013 and conduct estimations of panel probit models.

The analysis results highlight the importance of direct linkages, technology transfer between FDI firms and young SMEs, economic obstacles, and the interactions between them that cause SMEs to conduct R&D strategies in the supply chain (obtained through direct transfer of technology between linked firms). Specifically, our results indicate that firm size shows positive effects in all models of R&D. Our results confirm that firms which export do not tend to conduct an in-house R&D or both types of R&D, but are more likely to outsource. With respect to the market power of the firm and competition market at the national level, we also observe a significantly inversed U-shaped pattern for the probability of conducting in-house R&D or both types of R&D. The significantly positive impact has been found on the barriers of basic infrastructure on the probability of conducting in-house R&D, financial constraints on conducting outsourced R&D or both types of R&D, technological know-how on conducting in-house R&D, and technologies on conducting both types of R&D. Under the impact of FDI linkages and vertical R&D spillovers, first, for firms with FDI domestic customers, the significantly negative impact has been found on the barriers of communication infrastructure on the probability of conducting an in-house R&D. However, the significantly positive impact has been found on the barriers of transport infrastructure on the probability of conducting an in-house R&D. Constraint in financing on the other hand prevents firms to engage into an outsourced R&D. Among firms with FDI domestic customers resulted in technological transfer, the significantly negative impact has been found on the barriers of basic infrastructure on the probability of carrying out an outsourced R&D. Second, among firms with FDI domestic suppliers, the significantly positive impact has been found on the barriers of transport infrastructure on the probability of carrying out an outsourced R&D. In addition, constraint in technology know-how on the other hand prevents firms to exercise in-house R&D. Among firms with FDI domestic suppliers resulted in technological transfer, the significantly positive impact has been found on the barriers of transport infrastructure, and labor force on the probability of conducting an in-house R&D. Besides, among firms with FDI domestic suppliers resulted in technological transfer, the significantly negative impact has been found on the barriers of financing on the probability of conducting both types of R&D. While policies aiming to promote young SMEs' R&D obtain a consensus, it is less understandable why firms decide to undertake different types of R&D investment. Apart from firm's characteristics, FDI supply-chain linkages and technology transfer influence the firm's R&D behavior. Therefore, concerning policies must be aware that incentives along supply-chain may better reach the R&D outcomes for SMEs. Important equally, policy-makers must consider a broader range of economic and financial constraint that may influence R&D behavior, apart from export orientation, competitiveness, and market power.

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