Abandoning Innovation Projects, Filing Patent Applications and Receiving Foreign Direct Investment in R&D

Abstract

Foreign direct investment in R&D is one of the popular channels indigenous firms use to upgrade their technological capacities and improve market intelligence following innovation setbacks. Firms often employ various signals to secure higher levels of foreign direct investment in R&D. However, the majority of research on this topic focuses on the role of positive rather than negative signals. Firms are often conservative about communicating negative information regarding their innovation projects due to concerns around competition and managerial performance appraisal. Drawing on signaling theory, this study investigates the impact of a negatively valenced signal – the experience of abandoning innovation projects – on attracting foreign direct investment in R&D. Moreover, although firms are known to send multiple signals simultaneously, little is known about how the interactions between oppositely valenced signals (specifically, the experience of abandoning innovation projects, which is a negative signal, and the filing of patent applications, which is a positive signal) affect foreign direct investment in R&D. A study of 11,354 Spanish firms from the Spanish Technological Innovation Panel during the period 2008–2015 found that the experience of abandoning innovation projects has a positive effect on foreign direct investment in R&D. However, this positive effect is weakened by patent applications due to the signaling of conflicting messages. These results have important theoretical and practical implications for the advancement of signaling theory and the management of innovation setbacks.

Keywords: *Abandoned innovation, signaling theory, negative signals, multiple signals, patent applications, foreign direct investment in R&D.*

1. INTRODUCTION

Innovation is inherently risky, unpredictable and often oriented toward the long-term, with a substantial failure rate of approximately 40%–50% (Castellion and Markham, 2013). Firms that have abandoned innovation projects[1] often initiate technological searches beyond their knowledge base to break free from their failure traps (Su and McNamara, 2012). Foreign direct investment (FDI) in research and development (R&D) is one channel that is frequently used to transfer resources, such as new or advanced technologies, across national borders (Liu and Wang, 2003). The experience of abandoning innovation projects therefore organically attracts foreign investors who are able to exploit their superior capabilities, transfer these capabilities to the indigenous firms and help inefficient firms improve (García et al., 2013). In addition to capital, FDI allows firms to upgrade their technological know-how through training programs or technical assistance (Sultana and Turkina, 2020), and this is an important step of post-investment management. Having experience of failed innovation projects may also attract inorganic asset-exploiting foreign investors who want to substitute the innovation project with one from their home country or shift responsibility for innovation to more technologically capable parent firms (García et al., 2013).

Moreover, foreign investors also closely track signals of innovation abandonment because evidence shows that abandoned innovation projects are often aimed at attractive markets, which are more likely to be foreign, and exhibit high foreign market growth rates, making them highly relevant. This finding is based on Cooper and Kleinschmidt's (1990) study of 250 new industrial products from 125 industrial product firms. Firms that have abandoned innovation projects may require higher levels of FDI to help them conduct a more thorough home market

[1] Innovation projects include the acquisition of machinery, equipment, buildings, software and licenses; engineering and developmental work; feasibility studies; industrial design; and training and marketing that is carried out to develop product and/or process innovation. The category also includes all types of research and development. Abandoned innovation projects refer to those terminated once the activity or project started (Hu et al., 2017; Tsinopolous et al., 2019).

due diligence in terms of competition, distribution networks, consumer preference and international expansion opportunities (Gu and Lu, 2011).

The literature on signaling in innovation has overemphasized the intra-organizational implications of the experience of abandoning innovation projects but has overlooked it as a negatively valenced signal to the investment community – even though it indicates the existence of intermediate outputs that represent a critical developmental stage of innovation. It is becoming standard practice for firms to disclose information about innovation abandonment (Carman, 2019; Mcgee and Lee, 2020) (see Appendix 1 for examples). This signal improves information transparency and mitigates one of the major obstacles faced by foreign investors – information asymmetry (Audretsch et al., 2012; Kang and Kim, 2010). This study aims to shed light on how such signals affect firms' outcomes by focusing on the experience of abandoning innovation as a signal and how this affects FDI. Therefore, to address the aforementioned limitations and ambiguity, the first research question of this study is: *RQ1 – Does the experience of abandoning innovation projects help firms attract more foreign direct investment in R&D?*

Moreover, signalers send multiple signals to improve the likelihood of accurate interpretation (Filatotchev and Bishop, 2002). Prior studies of signaling have examined the relative importance of one type of signal in the presence of another (Connelly et al., 2011), focusing mainly on the interplay between positive signals. Within these studies, some positive signals were extrinsic and captured the attention of external stakeholders (Dai et al., 2018) – such as alliances, partners (Hu et al., 2017) and the market as a whole (Micheli and Gemser, 2016) – and some were intrinsic and firm-controlled – including scientific, market-based, location-based and historical signals (Hu et al., 2017; Micheli and Gemser, 2016). However, it is noteworthy that an investigation into the interplay between positive and negative signals is, so far, absent from the discussion in signaling-theory literature (Fischer

and Reuber, 2007). Given that firms do, in fact, send both types of signals to external stakeholders – either voluntarily or under compulsion – it is essential for managers to understand how oppositely valenced signals impact efforts to gain support and access resources from foreign investors.

In particular, the signal of abandoning innovation projects intrinsically entails higher uncertainty regarding returns on investment; such uncertainty can only be reduced with additional information on a firm's ability to recover from the negative experience. Venture capital firms screen potential portfolio firms to select those with the best growth perspectives based on innovative potential, which can be indicated by positively valenced signals, such as patent applications (Audretsch et al., 2012; Engel and Keilbach, 2007). As such, the following question was posed: *RQ2 – How does the interaction between experiences of abandoning innovation projects and filing patent applications impact foreign direct investment in R&D?*

Consequently, the main contributions of this study are twofold. First, it adds to signaling theory by demonstrating the effectiveness of one negatively valenced signal – the experience of abandoning innovation projects – for attracting FDI in R&D. Previous research into the experience of abandoning innovation projects is limited to the intra-organizational context (Desai, 2015; Madsen and Desai, 2010). The ways in which external investors react to these failures is still poorly understood (Urbig et al., 2013). This study builds a direct link between the internal and external context and theoretically explains how experiences of abandoning innovation can be positively associated with FDI. This provides a response to the scant body of research on negatively valenced signals (Connelly et al., 2011) and enriches the literature on recovering from innovation failure.

Second, there is a lack of research into the interplay between different types of signals (Micheli and Gemser, 2016) as well as how signal receivers – foreign investors – can perceive a mixture of signals differently (Connelly et al., 2011). We theorize the ways that oppositely valenced – positive and negative – signals interact in signal portfolios and whether they mutually strengthen, weaken, or neutralize one another's influence on attracting FDI in R&D. This investigation is valuable as it questions whether bundling signals with conflicting valences is effective, allowing investors to develop a meaningful evaluation of a firm's intrinsic quality (Fischer and Reuber, 2007). This question provides additional insight into traditional signaling theory, which assumes that firms process signals in isolation rather than assessing them holistically (Spence, 2002; Steigenberger and Wilhelm, 2018).

The next section reviews the relevant literature, hypothesizing that the experience of abandoning innovation projects promotes FDI and that this effect is moderated by patent applications, as shown in Figure 1. Following this, the data and methods adopted for testing the hypotheses are presented and the results are discussed. The paper concludes with a discussion of the findings and their implications.

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Insert Figure 1 about here

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2. THEORETICAL BACKGROUND AND CONCEPTUAL FRAMEWORK

2.1 Signaling theory

Signaling theory has been widely adopted in management and economics studies on acquisition premiums and post-initial public offering acquisitions (Reuer et al., 2012). The theory posits that firms possess observable, unalterable attributes, as well as unobservable attributes that are subject to manipulation (Spence, 1978). To bridge the information gap, stakeholders search for signals - observable actions - to provide information on a firm's unobservable attributes and likely outcomes (Spence, 1978).

The core argument in signaling theory is that the strategic disclosure of a company's private information is likely to mitigate the effects of information asymmetry (Bhattacharya and Ritter, 1983). However, firms encounter difficulties in conveying the quality of their innovations to the market due to the inherent uncertainty and secrecy of these innovations as well as the long-term intangible investment processes involved. This create the "lemons problem" for investors (Dai et al., 2018; Zhong, 2018), who must expend time and effort screening information in order to discover the true characteristics of the innovations (Barbaroux, 2014). In the literature on innovation, signaling theory provides a useful framework by which to understand how innovators use signals to disclose private information regarding the quality of their innovations to investors, thus reducing information asymmetry and adverse selection problems (Barbaroux, 2014). Innovation research has primarily focused on positive signals, such as technology and patents (Katila and Ahuja, 2002); design innovativeness (Micheli and Gemser, 2016); new product development alliances and the team experience (Hoenig and Henkel, 2015); founders, family and friends investment (Conti et al., 2013); and private equity investor involvement (Dutta and Folta, 2016).

However, there is a notable gap in the research regarding the effects of negatively valenced signals (Connelly et al., 2011), including the abandonment of innovation projects (Hu et al., 2017), the issuance of new shares to adjust for market overvaluation (Myers and Majluf, 1984), the sale of a large proportion of a firm during an initial public offering (Brau and Fawcett, 2006) and damage to reputation and the release of executive salary figures or stigmatized information (Steigenberger and Wilhelm, 2018). Negative signals can be particularly effective because they remove ambiguity in the innovation process and appear credible to signal receivers. Nonetheless, they are predominately treated as a consequence of insiders' actions being disclosed unintentionally rather than deliberately (Connelly et al., 2011).

2.2 Abandoning innovation projects as a signal

The literature on innovation failure centers around the intra-organizational performance implications of adverse innovation events. For example, studies have focused on the effects of these events on new product performance (Garzón-Vico et al., 2020; Kim and Miner, 2007; Madsen and Desai, 2010), firm performance (Desai, 2015; Madsen and Desai, 2010), R&D output (Khanna et al., 2016), future failure rates (Garzón-Vico et al., 2016) and exploitation and exploration (Su and McNamara, 2012). The findings report both positive and negative relationships. Positive relationships are often associated with internal improvements, reflection and vicarious learning, while negative relationships are associated with rising costs (Hu et al., 2015).

The ability to learn from innovation failure is central to the relationship between it and intra-organizational performance outcomes. The conditions that affect the ability to learn through innovation failure are the magnitude (large versus small) of the failure (Madsen and Desai, 2010), the internal distribution (concentrated versus dispersed) of failure events

(Desai, 2015), the relation to other interorganizational learning, proximity to the failure experiences of others (Kim and Miner, 2007) and external learning (Hu et al., 2015). Different forms or characteristics of experience may also influence the learning process and outcomes (Argote et al., 1990; Kim and Miner, 2007). For example, the outcomes of innovation failure depend on the rarity of the occurrence (Garzón-Vico et al., 2020), whether the failure is experienced first-hand, second-hand or within the industry and whether it is a complete or near failure (Kim and Miner, 2007).

However, there are a limited number of studies that explore the inter-organizational implications of the experience of abandoning innovation projects. Extant research finds that stock prices decline (Holmstrom, 1989; Sharma and Lacey, 2004). Urbig et al. (2013) examined 148 new product development (NPD) failures in publicly traded biopharmaceutical firms and their value destruction in terms of cumulative abnormal return. Hu et al. (2015) traced 180 public biopharmaceutical firms and found that innovation failure has a negative impact on the number of out-licensing deals. Hu et al. (2017) analyzed 248 alliances formed by 104 biotechnology firms from the United States and Europe and found both value-creating and value-destroying effects of innovation-failure signals on abnormal returns achieved from established co-development alliances.

The experience of abandoning innovation projects is often disclosed to foreign investors either reactively or proactively. First, firms, subjected to external pressure, reactively disclose experiences of abandoning innovation projects. Since the nature of foreign R&D investment entails high risk and is long-term oriented, foreign investors are keen to pursue critical information regarding R&D development and quality. Moreover, FDI is often established as a long-term relationship (Pajunen, 2008). It follows the process of the production of goods and services from initial transactions to subsequent capital and intermediate product

transactions such as innovation abandonment. The salience of the failure experience is more likely to attract the attention of foreign investors who are outcome-oriented (Garzón-Vico et al., 2020; Madsen and Desai, 2010). In some relationships, an intensive interaction persists from the beginning stages of innovation to the firm's maturity, and some investors may even influence the shared beliefs and attitudes about failure within the firm (García-Quevedo et al., 2018). Therefore, such key information is critical for foreign investors to make decisions on whether to increase or decrease their investment.

Moreover, external stakeholders (e.g., regulators) increase legitimacy pressure to encourage firms to provide supplementary disclosure regarding uncertainties surrounding internal R&D outcomes. For example, disclosure of innovation failure is compulsory for firms such as public and biotech firms. Such mandated disclosure enables regulators to better evaluate financial reports and enhance their understanding of off-balance sheet R&D assets (Madsen and Desai, 2010; Xu et al., 2007).

Second, firms are motivated to proactively disclose such experiences to access external resources. External disclosure affects learning efforts across poorly performing firms (Rhee and Haunschild, 2006). FDI facilitates the ability to learn from the failure through first-hand experience instead of indirect, vicarious learning, so firms often make information on the abandoned innovation projects accessible. This is supported by Kim and Miner (2007), who discovered that bank leaders are open about the conditions that prompted their banks' failures. This is also consistent with the findings of Madsen and Desai (2010) that failure experience induces firms to make their knowledge publicly available. They also found that external knowledge becomes more accessible after failures than after successes.

Although the experience of abandoning innovation projects is often associated with problems in a company's ability to manage its technology portfolio (Hu et al., 2017), it may also be the result of a series of managerial actions that have multiple, variable consequences

(Zhong, 2018). Owing to the importance of other antecedents of innovation performance, e.g., R&D expenses or open innovation activities – see Laursen and Salter (2006) and Klingebiel and Rammer (2014) – the experience of abandoning innovation projects is not a complete indication of a firm's overall innovation quality, and, as such, external investors may still be open-minded towards entrepreneurial firms with prior experience of abandoning projects (Cope et al., 2004; Leoncini, 2016). In fact, they often prefer to collaborate with firms that are honest about this kind of experience because such information signals transparency in a firm's innovation activities. Other positive indications include an increased knowledge stock from trial-and-error procedures (Leoncini, 2016) and a managerial ability to de-escalate commitment to one particular innovation and re-prioritize attention to other ongoing innovation projects (Sarangee et al., 2014). Given these benefits alongside the aforementioned transparency, the knowledge that a firm has abandoned innovation projects can allow investors to better estimate the return on their investment and engage in more efficient R&D expenditures (Zhong, 2018).

2.3 The interplay between positive and negative signals

Signaling theory assumes that signalers have the option to send multiple signals and identifies as a fruitful direction for future research the question of whether the use of a combination of signals enhances or diminishes the signaling process (Connelly et al., 2011). Firms in high-noise environments in particular favor sending a selection of substantive signals (Steigenberger and Wilhelm, 2018). While there have been empirical studies on the relative importance of signals where multiple signals are present, the majority of this research is based on the interplay between different types of positive signal (Micheli and Gemser, 2016).

An important consideration that has received limited scholarly attention is how foreign investors respond to mixed-valence signals that are discordant in direction (Connelly et al., 2011). When innovation abandonment is announced, investors do not know the full economic

implications, as such signals may not be released promptly, and this intrinsically entails high levels of uncertainty. Therefore, the experience of innovation abandonment only indicates an intermediate innovation status. However, the uncertainty can be reduced with additional information, i.e., additional signals, provided over time (Cabaleiro-Cerviño and Burcharth, 2020). The topic of this investigation is an important one, as sending a combination of oppositely valenced signals may cause a conflicting interpretation of the firm's innovation quality and confuse the signal receiver, ultimately resulting in less effective communication (Fischer and Reuber, 2007). Firms disclosing multiple signals need to achieve a balance between informing the market and assuring the confidentiality of their innovation projects in order to avoid the creation of conflicting messages.

Filing patent applications is a popular positively valenced signal of property rights and technological quality that is used to reduce information asymmetry when seeking external capital (Baum and Silverman, 2004; Hoenig and Henkel, 2015). Patents' signaling value can only be manifested when combined with additional signals, such as those signaling knowledge or project feasibility (Audretsch et al., 2012). Market investors, for example, often assess investment productivity signals to understand how productive a firm is at converting its expenditure into sales revenue that fuels future investments and capability-building (Hughes et al., 2019). Foreign investors, similarly, consider innovation productivity to gain a clearer picture of the quality of the outcomes after their injection of financial capital into a particular innovation activity.

Patent applications signal a strong R&D focus. Although it is essential for firms to complete the NPD process, a high number of patent applications can elevate investors' expectations for positive NPD outcomes (Urbig et al., 2013). This contradicts the message signaled by the abandonment of an innovation project and often leads to a more negative

reaction to this signal (Urbig et al., 2013), especially for products with long development cycles, such as those commonly seen in the biopharmaceutical industry. Patent applications are oriented towards the long term for products in late development stages and may insufficiently signal the firm's recovery potential in shorter NPD cycles, which might be more relevant for investors' ad hoc reactions to NPD failures. Therefore, signal portfolios need to be processed holistically. The combined effects of the two oppositely valenced signals on FDI depend on whether patent applications enhance message clarity and reduce the likelihood of misinterpretation of the negative signal, that of prior experience of abandoning innovation projects.

3. HYPOTHESIS DEVELOPMENT

3.1 The experience of abandoning innovation projects and foreign direct investment in R&D

The experience of abandoning innovation projects does not merely indicate a mismatch between ex-post innovation results and ex-ante innovation targets (Leoncini, 2016). It also signals to foreign investors about learning-by-failing opportunities and managerial attention allocation, which mitigate investors' perceptions of undue risks and market rumors. This means investors are better informed about potential returns and better equipped to understand how their R&D investments can be used most appropriately should they decide to proceed (Zhong, 2018).

The experience of abandoning innovation projects can indicate that a firm has learned to identify problems early, before they are irrevocably compounded (Cannon and Edmondson, 2005). Firms are able to more effectively comprehend problems if they have encountered

them while working on innovations they subsequently abandon, while experience and knowledge in managing innovation projects are accumulated (Leoncini, 2016). The knowledge and experience gained from abandoned innovation projects can also be transferred to ongoing projects, steering the firm away from the sub-optimal path they had been following (Elmquist and Le Masson, 2009). As such, the experience of abandoning innovation projects enhances a firm's capacity to learn from its deficiencies and prevent their reoccurrence, making it less likely to experience failure in future innovative projects (Cooper, 2008; Leoncini, 2016). This increases foreign investors' confidence and attracts more of their R&D funds.

The abandonment of an innovation project also signals a managerial ability to de-escalate commitments to previous innovation attempts and concentrate on ongoing innovation projects. Firms are able to investigate the reasons behind abandoned innovation, enhancing the project-screening processes and early termination decisions of other existing NPD projects with related technologies (Garzón-Vico et al., 2020). This allows the firm to redirect resources to other more promising projects or search for alternative solutions (Sarangee et al., 2014). There are also beneficial consequences to the abandonment decision: new products are made available to the market more quickly, efficiently and profitably (Cooper, 2008). Hence, the experience of abandoning projects increases foreign investors' confidence in the firm's cumulative learning process, as a firm is unlikely to carry a weak innovation portfolio following innovation setbacks (Love et al., 2020).

Finally, the experience of abandoning innovation projects improves the efficiency of the screening and matching process for focal firms and foreign investors. It signals to external investors the opportunity to accurately match their innovation specialty to the specific innovation problem that focal firms need to resolve. In the ex-ante contracting situation, focal

firms are more willing to adapt to those foreign investors that possess critical resources and skills that can contribute to the learning-by-failing process (Hu et al., 2017). Moreover, some asset-exploiting foreign investors shift the locus of innovative activities previously performed in the local market to the home country (García et al., 2013). This indicates that foreign investors can reap more rewards from making R&D investments in firms that have abandoned innovation projects, which encourages them to invest. Therefore, the following hypothesis was proposed:

H1: The experience of abandoning innovation projects is positively associated with foreign direct investment in R&D.

3.2 The combined effects of abandoning innovation projects and filing patent applications on foreign direct investment in R&D

The positive effects associated with the experience of abandoning innovation projects on FDI may be reduced if the focal firm files a large number of patent applications. While prior studies have found that an emphasis on appropriability – including patents – alone sends a positive signal to external stakeholders, overly restrictive protection mechanisms may deter stakeholders from becoming involved in innovation projects (Laursen and Salter, 2014). The value of patents is known to be highly skewed, with a minority concentrating on narrow technological fields, yet accounting for the majority of economic returns (Scherer and Harhoff, 2000). A substantial number of patents are filed for purely strategic reasons rather than to protect significant inventions (Torrisi et al., 2016). For example, numerous "blocking to fence" patents may be filed on different aspects of the same technology used by the competition (Blind et al., 2009). Consequently, a large number of patent applications raises concerns for investors who need to verify whether they have been filed to protect internal R&D efforts that will result in observable revenue or for strategic reasons, of which the

technological value is relatively more obscure (Torrisi et al., 2016). Foreign investors may assign a lower value to the signal of the experience of abandoning innovation projects if the signal of a high number of patent applications is present at the same time.

Moreover, the filing of many patent applications contradicts the implications of abandoning innovation projects. This is because the former suggests the strong possibility of heavy managerial attention on protective activities surrounding completed innovations, whereas the latter implies that managerial attention is concentrated on the learning-from-failure process and/or on developing ongoing innovation projects. Information about the managerial focus is therefore conflicting or incoherent, which consequently confounds foreign investors and subsequently reduces their direct investment in R&D.

Furthermore, given that a large number of patent applications signals a strong intent to protect knowledge from misappropriation (Storey and Tether, 1998), foreign investors may question how open the focal firm will be in terms of sharing the knowledge learned from abandoned innovation projects, as well as the extent to which the investors will benefit from R&D investment. Therefore, the abandonment of innovation projects and the filing of many patent applications present conflicting information: innovation abandonment signals that the innovator is strongly motivated to seek external solutions to innovation problems by finding an investor who can contribute the critical resources and skills, whereas filing many patent applications signals a strong intention to resolve innovation problems internally. This is liable to cause conflict over the control, ownership and appropriation of created solutions and knowledge (Laursen and Salter, 2014) and complicate the decision-making process, thereby reducing the attractiveness to foreign R&D investors. As such, the following hypothesis was proposed:

H2: Patent applications have negative moderating effects on the positive relationship between the experience of abandoning innovation projects and foreign direct investment in R&D.

4. METHODOLOGY

4.1 Data

The dataset used in this study was compiled from Spain's Community Innovation Survey (CIS), which was administered by the Spanish National Statistics Institute. Spain's CIS is a firm-level panel dataset that provides a vast amount of information to quantify firms' innovation activities and evaluate innovation capabilities and outputs. The questionnaire was based on the European CIS, which has high levels of interpretability, reliability and validity (Laursen and Salter, 2006) and has been widely used in economics and management studies – for important studies using CIS data, please see Cassiman and Veugelers (2002) and Laursen and Salter (2006).

The rationale for choosing Spain as the context for this analysis was threefold. First, Spain has a relatively low R&D intensity compared to other EU countries (Coad et al., 2016). This meant that the study herein, regarding the effects of the experience of abandoning innovation projects in relation to attracting foreign R&D investment, would be most relevant for moderate- and slow-growing innovators. Second, the Spanish innovation system involves a high level of international support: 5.1% of firms attract EU support. This figure is higher than in other leading innovation countries, such as the UK where it is 1.7% (Becker et al., 2017). Spain thus provides a suitable context in which to understand how innovation activities impact foreign R&D investment. Third, given that the dependent variable in this study was foreign direct investment in R&D, this dataset seemed appropriate since it allowed for the identification of the amount of foreign R&D funds received, while this was measured

as a binary variable in other European countries, such as the UK. Moreover, firms are under a legal obligation to complete the questionnaire in Spain, and the survey data is collected annually, with an average response rate of 90%.

The data used in this study was collected between 2008 and 2015, and the subsequent analysis was based on firm-year units. The independent, moderating and control variables were lagged by one survey period to the dependent variable to take the time-lag effect into account and suggest causal inference. This resulted in data collection from 11,354 firms, among which 1,597 were foreign-affiliated firms and 9,757 were domestic, with 74,258 observations across the eight-year period.

4.2 Measures

4.2.1 The dependent variable

Foreign direct investment in R&D (FOREIGN). Firms finance internal R&D via foreign organizations, such as public administration bodies, companies, research associations, universities and private, non-profit institutions. FOREIGN was measured by taking the natural logarithms of internal R&D expenses from foreign organizations.

4.2.2 The independent variable and moderators

Experience of abandoning innovation projects (ABANDON). This identified whether a firm's innovation activities had been abandoned during the three years preceding the survey period[2]. It was coded as "0" when a firm did not exhibit such activity and "1" when a firm did.

[2] Our research focuses on one type of innovation failure (i.e., abandonment), rather than other types (e.g., suspension), which is consistent with the measurement specified in the CIS questionnaire. For example, one question in the 2015 CIS questionnaire asked, "In the 2013-2015 period, were any of your innovation activities or projects abandoned in the conception phase?" and the following question asked, "In the 2013-2015 period, were any of your innovation activities or projects abandoned once the activity or project started?"

Number of patent applications (PATENT). Filing patents is one of the most important means of protecting intellectual property rights. "PATENT" denoted the efforts a firm made to protect its intellectual property by raising its innovation activity level and was measured by taking the natural logarithms of the number of patent applications.

4.2.3 Control variables

Internal and external R&D investment. Firms' R&D activity was measured using two variables – INTRD and EXTRD. Both variables measured the level of a firm's commitment to R&D activities: INTRD was measured using the natural logarithms generated from the fraction of the internal R&D expenditure out of total R&D expenditure and EXTRD was measured by the fraction of the natural logarithms of the external expenditure out of total R&D expenditure.

Firm size. A firm's engagement in foreign R&D financing may vary across small- and medium-sized firms and large-sized firms. SIZE was measured according to the natural logarithms of the number of employees (Brouwer and Kleinknecht, 1999; Danneels and Sethi, 2011). Moreover, the effect of firms' ownership type on foreign R&D funds was considered, which was indicated by the control variable *Firm type*.

Labor intensity. This was used to capture the turnover per employee and was measured using the natural logarithms of the ratio of turnover to the number of employees (Baldwin and Gu, 2004).

Firm type. As Spain's CIS included an indicator clarifying the range of foreign capital for each firm, it was possible to identify a firm's foreign ownership type. This was a categorical variable ranging from one to six, indicating public firms, private national firms, private

multinational firms with less than 10% foreign capital, private multinational firms with at least 10% but less than 50% foreign capital, private multinational firms with at least 50% foreign capital and other types.

Furthermore, it is worth noting that both R&D financing and innovation activities may vary substantially across different industry sectors due to the level of internal R&D activity development. In order to conduct the multilevel mixed-effects Tobit regression analysis, a two-digit Standard Industrial Classification (SIC) code was used to classify 43 manufacturing industries. *Region* identified the location of a firm's headquarters and was coded according to five territory-level dummy variables – Madrid, Cataluña, Andalucía,[3] the rest of Spain and the rest of the world. Year dummy variables from 2008 to 2015 were also included in the analysis to catch unobserved across-time endogeneity.

4.3 Methods

In order to empirically examine the effects of the experience of abandoning innovation projects and the number of patent applications on foreign direct investment in R&D, the estimator was composed based on a firm-year unit. Four hierarchical models were employed to test the hypotheses by placing the control, independent and moderating variables into regression, step by step. First, a model was predicted, which included only the control variables – Model 1: internal and external R&D investment, firm size, labor intensity, firm ownership type, year dummy, industry random intercept and region random intercept. Next, the key independent variable (ABANDON) was entered into Model 2, and the moderator (PATENT) was added to Model 3. Then, the hypothesized two-way interactions between

[3] These territories are the three largest by population in Spain.

ABANDON and PATENT were estimated in Model 4. Table 1 shows the variable definitions and model specifications.

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The multilevel mixed-effects Tobit model was adopted for two reasons. First, 75% of firms did not engage in internal R&D activities, so the dependent variable was left-censored. Therefore, the estimate model was designed to address the censoring feature of the dependent variable (Wooldridge, 2002). Second, the estimate model was intended to address any unobserved heterogeneity in the impact of experiences of abandoning innovation projects on foreign R&D funds due to the cross-industry nature of the dataset. The multilevel mixed-effects Tobit model was further used to account for the hierarchical structure of the selected dataset, which denoted that the clustering of the firm-level data was within individual industries. The likelihood-ratio test comparing the estimate model with a Tobit model was significant at the 0.01 level, which suggested that the multilevel mixed-effects Tobit model was preferable. The estimated residual variance in the random intercept was significant at the 0.001 level, indicating that the choice of multilevel modelling with industry effects was appropriate. Table 2 shows the descriptive statistics, with variance inflation factor (VIF) values ranging from 1.01–1.40. The presence of low VIF values lent strong support to the notion that multicollinearity was not a concern in this study.

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Insert Table 2 about here

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5. RESULTS

5.1 Hypotheses testing

Table 3 shows the results of Models 1–4. H1 predicted that the experience of abandoning innovation projects would have positive effects on foreign direct investment in R&D. As Table 3, Model 2 demonstrates, ABANDON ($\beta = 0.609$, $p < 0.01$) was positively related to FOREIGN. In other words, when a firm had an experience of abandoning innovation projects, it was more likely to procure foreign direct investment in R&D; therefore, H1 was supported. Patent application activity exhibited significant and positive relationships with foreign direct investment in R&D (Table 3, Model 3 [Export: $\beta = 0.562$, $p < 0.001$]). The results suggested that an increase in the number of patent applications was associated with an increase in foreign direct investment in R&D.

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Insert Table 3 about here

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The results of the regression analyses depicted in Table 3, Model 4 provide information related to H2, which predicted that patent applications would weaken the positive relationship between the experience of abandoning innovation projects and foreign direct investment in R&D. This two-way interaction term was entered into Model 4 to clarify the interaction

effect for interpretation. The interaction term was negative, as depicted in Table 3 (ABANDON × PATENT: β = -0.440, $p < 0.01$). The moderating effect of the number of patent applications on the relationship between the experience of abandoning innovation projects and foreign direct investment in R&D is demonstrated in Figure 2.

The effect of the experience of abandoning innovation projects on FOREIGN was tested and was conditional at different levels (±1 SD) of the patent applications. In predicting FOREIGN based on Model 4 (Figure 2), the slope for the low patent application level was positive and significant ($\gamma = 0.548$, $p < 0.01$). The slope was also positive and significant in cases of high patent application levels ($\gamma = 0.152$, $p < 0.01$). The line representing high patent application levels (the circle line) remained consistently above the line representing low patent application levels (the triangular line). The higher level of FOREIGN in Figure 2 was thus achieved when patent applications levels were high. However, the effect of the experience of abandoning innovation projects on FOREIGN was stronger when patent application levels were low but weaker when they were high (0.548 vs 0.152); therefore, H2 was supported.

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Insert Figure 2 about here

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5.2 Robustness check

Several robustness tests were conducted to evaluate whether the findings held true across dependent variable specifications and samples. First, an examination was conducted into whether the models were subject to alternative estimate methods. Models 5–8 were generated by adopting ordinary least squares and the Tobit model, using the panel effect Tobit and the

random logistic models[4] to replace the mixed-effect Tobit model in Model 4. The results of Models 5–8 (Table 4) indicated the positive impact of the experience of abandoning innovation projects on FOREIGN as well as a significant interaction term between this experience and patent application activity. The consistent results of Model 4 (Table 3) and those of Models 5–8 (Table 4) indicated that the findings of the study were robust across a variety of estimate methods. Second, a propensity score-matching analysis was conducted to mitigate any selectivity bias caused by the firm-level characteristics of firms with experience of abandoning innovation projects, which lead to greater foreign R&D investment (Caliendo and Kopeinig, 2008). The results of the matching approach (Model 9, Table 4) were highly consistent with those of the main model (Model 5, Table 3). As such, this additional robustness check lent further support to the findings and addressed the endogeneity issue to a certain extent. Nevertheless, it was acknowledged that the interpretation of the results was contingent on the potential for endogeneity. The results of Models 5–8 are reported in Table 4.

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Insert Table 4 about here

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Third, we used an alternative measurement of ABANDON to test the robustness of the measurement of this variable in Model 4. We first generated a balanced dataset from 2008 to 2015 to create a reliable measurement to count the number of times that a firm abandoned

[4] A dummy variable was used to represent whether or not a firm had foreign funds for internal R&D.

innovation projects across all eight survey waves. We then used this count measurement to replace the dummy measurement in Model 4 and ran a multi-level mixed Tobit model in Model 10. Moreover, we generated a binary variable to measure whether a firm has not experienced abandoned innovation/experienced it one time or experienced it multiple times across all eight survey waves. This variable is used to indicate whether firms have had more than one abandonment experience. We then used this alternative binary measurement in Model 4 and ran a multi-level mixed Tobit model in Model 12. The results of Model 4 were highly consistent with those of Models 10 and 12. Fourth, we generated a count variable, *Average failures for each industry*, to measure the average number of abandoned innovations in an industry (number of failures per industry per year divided by number of firms per industry per year) based on a two-digit industrial code. This was done to account for the differences in experiences of failure across industries. We then used it as a control variable and added it into Model 10 and Model 12, generating Model 11 and Model 13. The coefficients of this additional control variable were insignificant, which shows that it did not increase the predictive capacity of the estimates. More importantly, the coefficients of all variables were highly consistent between Model 10 and 11 and between Model 12 and 13, indicating that differences in abandoned innovation activities across industries did not bias our results. The results of Models 10–13 are reported in Table 5.

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Insert Table 5 about here

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6. DISCUSSION AND IMPLICATIONS

6.1 Theoretical implications

This study provides theoretical and empirical support for the signaling role of the experience of abandoning innovation projects in spurring foreign direct investment in R&D and is one of the few to examine the combined impact of positively and negatively valenced signals on attracting such funds. It contributes to signaling theory by expanding its application in innovation literature in two ways. First, it was confirmed that the experience of abandoning innovation projects is a negatively valenced but relevant signal to foreign investors. This represents an important step forward in understanding the benefits of negatively valenced signals (Spence, 1978) by providing strong evidence of a positive link between the experience of abandoning innovation projects and FDI. An explanation for this is that the experience of abandoning innovation projects communicates information about valuable and transferable learning-by-failing opportunities and the concentration of managerial attention on remaining innovation projects, both of which mitigate information asymmetry in foreign investors' decision-making processes (Hu et al., 2017). This corroborates the view that negatively valenced signals are often more diagnostic and revealing than positively valenced ones (Fischer and Reuber, 2007). Given that the evaluation of investments in R&D projects is more complex than in other projects, gaining a complete understanding of a firm's overall innovation quality is impossible in most scenarios (Mina et al., 2013). However, the signal of abandoned innovation projects can profoundly help investors overcome informational asymmetry. This study, therefore, offers a novel inter-organizational perspective for understanding the underestimated effect of the experience of abandoning innovation projects.

Second, through examining the impact of the combined influence of positively and negatively valenced signals – filing patent applications and abandoning innovation projects, respectively – this research has responded to the need to interpret signals holistically rather

than in isolation, which was missing from previous studies of signaling (Connelly et al., 2011). It is known that multiple signals can improve the accuracy of interpretations by external stakeholders (Filatotchev and Bishop, 2002). Nonetheless, there was lack of understanding regarding the impact of sending multiple signals with fragmented, incoherent and inconsistent messages on firms' outcomes.

The findings of this study show that patent applications weaken the relationship between the experience of abandoning innovation projects and FDI in R&D. This suggests that filing patent applications and abandoning innovation projects send conflicting signals to foreign investors. On the one hand, the experience of abandoning projects indicates the availability of valuable and transferable learning-by-failing opportunities, concentrated managerial attention on ongoing innovation projects and willingness to adapt to external critical resources and skills to resolve innovation problems. On the other hand, the filing of a large number of patent applications suggests a strong intention to seek solutions internally. It signals that the focal firm has diverted investment to protect completed innovations rather than ongoing ones. Additionally, it indicates that the firm is less likely to relinquish control over intellectual property rights. These inconsistent messages diminish the credibility and attractiveness of the signal of abandoned innovation projects, thereby reducing foreign direct investment in R&D. Overall, the results contribute to signaling theory by showing that conveying two types of signals – positively and negatively valenced signals – at the same time creates confusion for signal receivers, as firms exhibit inconsistency in their innovation behaviour and strategic intentions. Consequently, external stakeholders are unlikely to make consistent assumptions about the firm's attributes (Fischer and Reuber, 2007). This weakens the message that is communicated, which, in this context, results in reduced foreign direct investment in R&D.

6.2 Managerial implications

These findings have significant practical implications for innovators, foreign investors and public policymakers. First, the experience of abandoning innovation projects should not be seen exclusively as a disadvantage in the capital market but as an opportunity to attract purposive R&D investment. This research emphasizes the importance of disclosing the experience of abandoning innovation projects if the aim is to obtain greater financial and managerial assistance following such an experience. Managers should be aware that the experience of abandoning innovation projects is acceptable, diagnostic and transferable to other ongoing innovation projects from a foreign investor's perspective. The potential channels for signaling are public announcements, press releases, company prospectuses, network referrals and direct approaches to investors. It is also worth noting that firms often fall into the trap of bombarding external stakeholders with numerous types of signals and, as such, should ensure that these multiple signals communicate a set of consistent messages (Balboa and Martí, 2007). An example from this study is that reconsideration should be given to signaling patent applications in conjunction with the experience of abandoning innovation projects due to the contradictory nature of the messages they deliver. Firms need to consistently communicate multiple signals that convey their various attributes, and these messages should conflict as little as possible (Gao et al., 2008).

6.3 Limitations and future research

There were several limitations in this study that could be explored in future research. First, the purpose of foreign investment is to fund focal firms' R&D activities, which limited this analysis to the domain of attracting R&D funds for internal purposes. Further research could

explore the role of the experience of abandoning innovation projects in other domains, such as other types of foreign investment, including funding for external R&D, horizontal, vertical or conglomerate investments or a foreign takeover (Moosa, 2002), or innovation strategy reconfigurations, such as a switch from exploitation-focused to exploration-focused innovation. Second, one interesting source of firm-level heterogeneity is the relationship between foreign investors and focal firms. CIS does not include information on whether and for how long foreign investors had worked with focal firms or whether abandoned innovation was disclosed proactively or reactively. Signals need to be interpreted cautiously, because firms can be dishonest for the sake of guarding against issues of competition and managerial performance appraisal. These issues could be investigated in finer detail in future studies. Third, this study's theoretical contribution suggests that a set of signals with conflicting messages confuses investors and is associated with non-favorable investment outcomes. However, this finding should be interpreted with some caution. For example, while objective measures were used regarding the amount of foreign R&D funds a focal firm obtained, there was a lack of subjective measures relating to how foreign investors perceived signals generated by focal firms' experience of abandoning innovation projects and filing patent applications. Such subjective measures would have been useful for validating the arguments. As such, future studies might conduct a qualitative analysis to better understand how foreign investors decode a combination of signals for R&D funding decision making. Fourth, this study relied upon a static interpretation of the value of information regarding abandoning innovation projects and filing patent applications. Future research might additionally explore whether and how frequently firms renew information on these signals to allow investors to update their initially formed expectations (Haeussler et al., 2014). Fifth, although we followed previous learning-from-failure research (e.g., Madsen and Desai, 2010; Hu et al., 2017; Tsinopoulos et al., 2019), and we assume the critical role of learning after innovation

abandonment, our data does not enable the observation of this learning. Future research can advance this point by using greatly enriched empirical evidence. Sixth, the unit of analysis is at firm level; a future study might extend the analysis to project level and introduce the experience of abandoning innovation as a count variable to provide further insights. Seventh, future studies could consider other organization-level innovation characteristics or industry-level failure experiences and their interactions with the experience of abandoning innovation projects to potentially explain variance in foreign investors' reactions to this signal. Finally, this paper only focuses on one type of innovation failure (i.e., abandoned) and has not considered other types of innovation failure (e.g., suspended). As indicated by Hu et al. (2017), the quality of investment potential and the possibility of restarting a failed project differ between different types of failures. Future studies can compare the signaling effect of different types of innovation failure on firm outcomes, for example, between suspension and abandonment.

7. Appendix

Appendix 1. Examples of disclosing innovation abandonment

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Table 1: Variable Definitions in Spain's CIS dataset for 2008–2015

Equation 1: $FOREIGN_{it}=\beta_{10}+\beta_{11}\,Control\ Variables_{i,\,t-1}+\varepsilon_{i,t-1}$

Equation 2: $FOREIGN_{it}=\beta_{20}+\beta_{21}\,ABANDON_{i,t-1}+\beta_{22}Control\ Variables+\varepsilon_{i,t-1}$

Equation 3: $FOREIGN_{it}=\beta_{30}+\beta_{31}\,ABANDON_{i,t-1}+\beta_{32}PATENT_{i,t-1}+\beta_{33}Control\ Variables+\varepsilon_{i,t-1}$

Equation 4: $FOREIGN_{it}=\beta_{40}+\beta_{41}\,ABANDON_{i,t-1}+\beta_{42}PATENT_{i,t-1}+\beta_{43}\,ABANDON*PATENT_{i,t-1}+\beta_{44}Control\ Variables+\varepsilon_{i,t-1}$

	Definitions
FOREIGN	Foreign direct investment in R&D. The natural logarithms of the fraction of the total internal expenses on R&D that comes from foreign companies, foreign research associations, foreign public administration bodies, foreign universities and private, non-profit institutions
ABANDON	Experience of abandoning innovation projects. Binary variable '0': a firm has no experience of abandoning innovation projects in the previous three years; '1': it has experience of abandoning innovation projects
PATENT	Patent applications. The natural logarithms of the number of patent applications during the previous three years.
ABANDON*PATENT	Interaction term of ABANDON and PATENT
Control variables	
INTRD	Internal R&D expense intensity. The natural logarithm of the fraction of in-house R&D investment
EXTRD	External R&D expense intensity. The natural logarithms of the fraction of external R&D investment
EMPLOYMENT	Employment size. The natural logarithm of number of employees
LABOUR	Firms' turnover per employee. The natural logarithms of the ratio of turnover to number of employees
FIRMTYPE	Firm type. The firm type includes 1: public firms, 2: private national firms, 3: private multinational firms with less than 10% foreign capital, 4: private multinational firms with at least 10% but less than 50% foreign capital, 5: private multinational firms with at least 50% foreign capital and 6: research association and other research institutions.
REGION	Regional dummy variable representative of the following areas: Madrid, Cataluña, Andalucía, rest of Spain and rest of the world
INDUSTRY	Industry dummy variable representative of 43 SIC codes, which are sub-classifications of manufacture, mining, electricity & water supply, construction, hotel & accommodation, transportation and other
YEAR	Time dummy variable representative of nine survey periods from 2008–2015
ε_i	Random error term
β_0–β_5	Model coefficients, where β_0 measures the constants; β_1 measures the relationship between experience of abandoned innovation and FOREIGN; β_2 measures the relationship between patent applications and FOREIGN; β_3 measures the moderating effects of patent applications on the relationship between experience of abandoned innovation and FOREIGN

Table 2: Descriptive Statistics and Correlation Coefficients

	Variable	1	2	3	4	5	6	7	8	9	10	Mean	SD	Min	Max	VIF
1	FOREIGN											0.09	0.53	0	4.62	
2	ABANDON	0.05*										0.2	0.4	0	1	1.09
3	PATENT	0.13*	0.15*									0.12	0.45	0	6.75	1.13
4	INTRD	0.20*	0.27*	0.28*								5.78	6.29	0	20.03	1.4
5	EXTRD	0.14*	0.18*	0.24*	0.48*							2.56	4.84	0	19.17	1.34
6	EMPLOYMENT	0.02*	0.14*	0.08*	0.27*	0.22*						4.22	1.65	0.69	10.63	1.31
7	LABOR	-0.05*	0.07*	0.05*	0.12*	0.13*	0.10*					11.72	1.13	0	19.40	1.24
8	FIRMTYPE	0.03*	0.13*	0.04*	0.13*	0.10*	0.33*	0.13*				2.45	1.11	1	6	1.16
9	REGION	0.01	-0.11*	0.01	-0.08*	-0.04*	-0.31*	-0.08*	-0.71*			2.89	1.22	1	4	1.09
10	INDUSTRY	0.09*	-0.10*	-0.04*	-0.12*	-0.08*	0.06*	-0.33*	-0.15*	0.07*		22.71	12.16	0	43	1.18
11	YEAR	0.05*	-0.07*	-0.01*	-0.12*	-0.09*	-0.18*	0.00	-0.17*	0.17*	0.01	2011.15	2.23	2008	2015	1.01

*Correlation is significant at 0.05 levels. N=74,258

Table 3: Experience of Abandoning Innovation Projects' Effect on Foreign Direct Investment in R&D

	Multilevel Mixed-Effect Tobit Model							
	Model 1		**Model 2**		**Model 3**		**Model 4**	
Dependent variable: FOREIGN	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
ABANDON			0.476***	(2.59)	0.430**	(2.27)	0.609***	(3.23)
PATENT					0.350***	(3.83)	0.562***	(4.93)
ABANDON *PATENT							-0.440***	(-2.59)
Controls								
INTRD	0.496***	(8.53)	0.491***	(8.48)	0.480***	(8.15)	0.478***	(8.17)
EXTRD	0.112***	(3.56)	0.109***	(3.52)	0.105***	(3.46)	0.104***	(3.43)
EMPLOYMENT	0.267***	(3.40)	0.251***	(3.23)	0.217***	(2.75)	0.220***	(2.78)
LABOR	-0.189	(-1.62)	-0.193	(-1.64)	-0.197*	(-1.65)	-0.195	(-1.64)
FIRMTYPE (Research institute as base)								
Public	-0.239	(-0.58)	-0.209	(-0.52)	-0.141	(-0.35)	-0.125	(-0.31)
National private	-2.344***	(-8.94)	-2.342***	(-9.17)	-2.311***	(-9.46)	-2.295***	(-9.38)
Multinational private <10%	-2.653***	(-7.70)	-2.706***	(-7.92)	-2.697***	(-7.95)	-2.653***	(-7.83)
Multinational private ≥10%<50%	-2.451***	(-4.84)	-2.452***	(-4.82)	-2.430***	(-4.71)	-2.421***	(-4.69)
Multinational private ≥50%	-3.318***	(-9.29)	-3.313***	(-9.42)	-3.250***	(-9.44)	-3.225***	(-9.26)
Industry random intercept	2.927***	(3.90)	2.949***	(3.88)	2.878***	(3.84)	2.904***	(3.82)
Regional dummies	Included		Included		Included		Included	
Year dummies	Included		Included		Included		Included	
No. of observation	74258		74258		74258		74258	
Wald Chi Square	1739.347		2139.935		2791.627		2801.571	
Prob>chi2	0.000		0.000		0.000		0.000	
AIC	25723.862		25700.953		25672.428		25659.446	
BIC	25926.598		25912.905		25893.595		25889.829	

Note: * p<0.1, ** p<0.05, *** p<0.01

Table 4: Robustness Check for Abandoned Innovation Activity Effect on Foreign Funds for Internal R&D

Dependent variable: NPI	**Model 5 OLS**		**Model 6 Tobit**		**Model 7 Random Tobit**		**Model 8 Matching**	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
FAIL	0.023***	(3.98)	0.615***	(5.81)	0.497***	(4.83)	0.460***	(4.31)
PATENT	0.074***	(8.08)	0.560***	(6.76)	0.487***	(5.89)	0.460***	(6.17)
FAIL*PATENT	-0.031**	(-2.43)	-0.447***	(-3.93)	-0.323***	(-2.97)	-0.400***	(-4.05)
Controls								
INTRD	0.010***	(26.27)	0.476***	(28.75)	0.299***	(21.78)	0.578***	(16.74)
EXTRD	0.006***	(10.69)	0.104***	(13.02)	0.056***	(6.94)	0.088***	(10.63)
EMPLOYMENT	0.013***	(9.23)	0.224***	(6.75)	0.332***	(6.72)	0.139***	(3.60)
LABOR	-0.007***	(-2.94)	-0.188***	(-4.24)	-0.044	(-0.90)	-0.244***	(-4.92)
FIRMTYPE (*Other* as base)								
Public	-0.494***	(-9.53)	-0.131	(-0.48)	-0.150	(-0.38)	-0.309	(-1.06)
National private	-0.696***	(-14.89)	-2.247***	(-10.80)	-1.704***	(-6.08)	-2.105***	(-9.86)
Multinational private <10%	-0.727***	(-15.01)	-2.605***	(-6.89)	-2.084***	(-5.11)	-2.405***	(-6.38)
Multinational private ≥10%<50%	-0.696***	(-14.23)	-2.391***	(-7.45)	-1.893***	(-4.80)	-2.470***	(-7.80)
Multinational private ≥50%	-0.734***	(-15.63)	-3.178***	(-12.48)	-2.366***	(-7.20)	-3.034***	(-11.80)
Industry dummies	Included		Included		Included		Included	
Regional dummies	Included		Included		Included		Included	
Year dummies	Included		Included		Included		Included	
No. of observation	74258		74258		74258		28892	
Wald Chi Square	F-statistics = 51.932		8825.547		1403.101		1058.805	
Prob>chi2	0.000		0.000		0.000		0.000	
AIC	103707.663		25567.909		21562.588		17848.798	
BIC	104315.873		26185.334		22189.228		18055.581	

† Level 1: 43 industries; * p<0.1 ** p<0.05 *** p<0.01

Table 5: Robustness Check for Abandoned Innovation Activity Effect on Foreign Direct Investment in R&D- Alternative measurement of Abandoned Innovation Activity

Dependent variable: NPI	Model 10 Counted Fail Measurement		Model 11 With Average Industry Fail as Control		Model 12 Single/Multiple Fail Measurement		Model 13 With Average Industry Fail as Control	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Number of FAIL across Waves	0.130***	(2.88)	0.130***	(2.88)				
Single/Multiple Fail					0.566**	(2.50)	0.567**	(2.51)
PATENT	0.635***	(4.80)	0.635***	(4.82)	0.790***	(5.53)	0.790***	(5.55)
Number of FAIL*PATENT	-0.068**	(-2.43)	-0.068**	(-2.43)				
Single/Multiple Fail*PATENT					-0.496***	(-3.22)	-0.496***	(-3.22)
Controls								
Average Fail for each Industry			-0.699	(-0.46)			-0.670	(-0.43)
INTRD	0.469***	(8.30)	0.470***	(8.32)	0.476***	(8.21)	0.476***	(8.23)
EXTRD	0.106***	(3.44)	0.106***	(3.44)	0.109***	(3.49)	0.109***	(3.49)
EMPLOYMENT	0.176**	(2.29)	0.176**	(2.28)	0.192**	(2.42)	0.192**	(2.41)
LABOR	-0.166	(-1.37)	-0.166	(-1.37)	-0.161	(-1.32)	-0.160	(-1.31)
FIRMTYPE (*Other* as base)								
Public	-0.190	(-0.46)	-0.195	(-0.48)	-0.210	(-0.50)	-0.215	(-0.52)
National private	-2.398***	(-10.54)	-2.402***	(-10.57)	-2.408***	(-9.96)	-2.411***	(-10.00)
Multinational private <10%	-2.754***	(-7.44)	-2.759***	(-7.50)	-2.703***	(-7.49)	-2.708***	(-7.54)
Multinational private ≥10%<50%	-2.467***	(-4.52)	-2.469***	(-4.52)	-2.481***	(-4.48)	-2.483***	(-4.48)
Multinational private ≥50%	-3.317***	(-9.89)	-3.318***	(-9.90)	-3.333***	(-9.74)	-3.335***	(-9.74)
Industry dummies	Included		Included		Included		Included	
Regional dummies	Included		Included		Included		Included	
Year dummies	Included		Included		Included		Included	
No. of observation	63063		63063		63063		63063	
Wald Chi Square	2807.074		2837.796		2084.060		2128.560	
Prob>chi2	0.000		0.000		0.000		0.000	
AIC	22552.349		22554.079		22562.959		22564.711	
BIC	22769.594		22780.376		22780.205		22791.008	

† Level 1: 43 industries; * p<0.1 ** p<0.05 *** p<0.01

Figure 1. Conceptual Framework

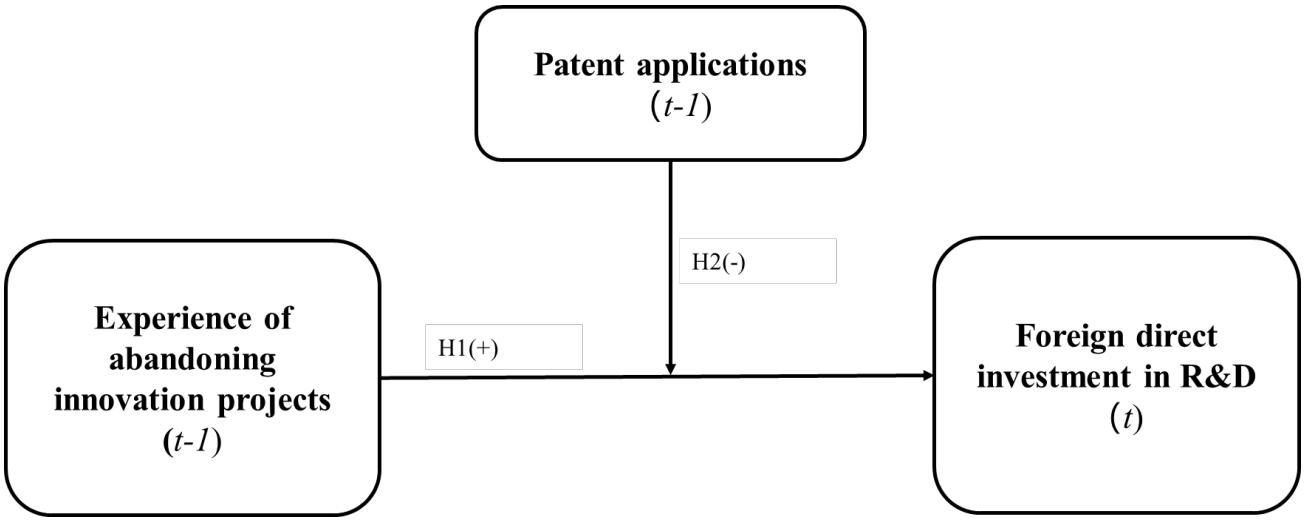
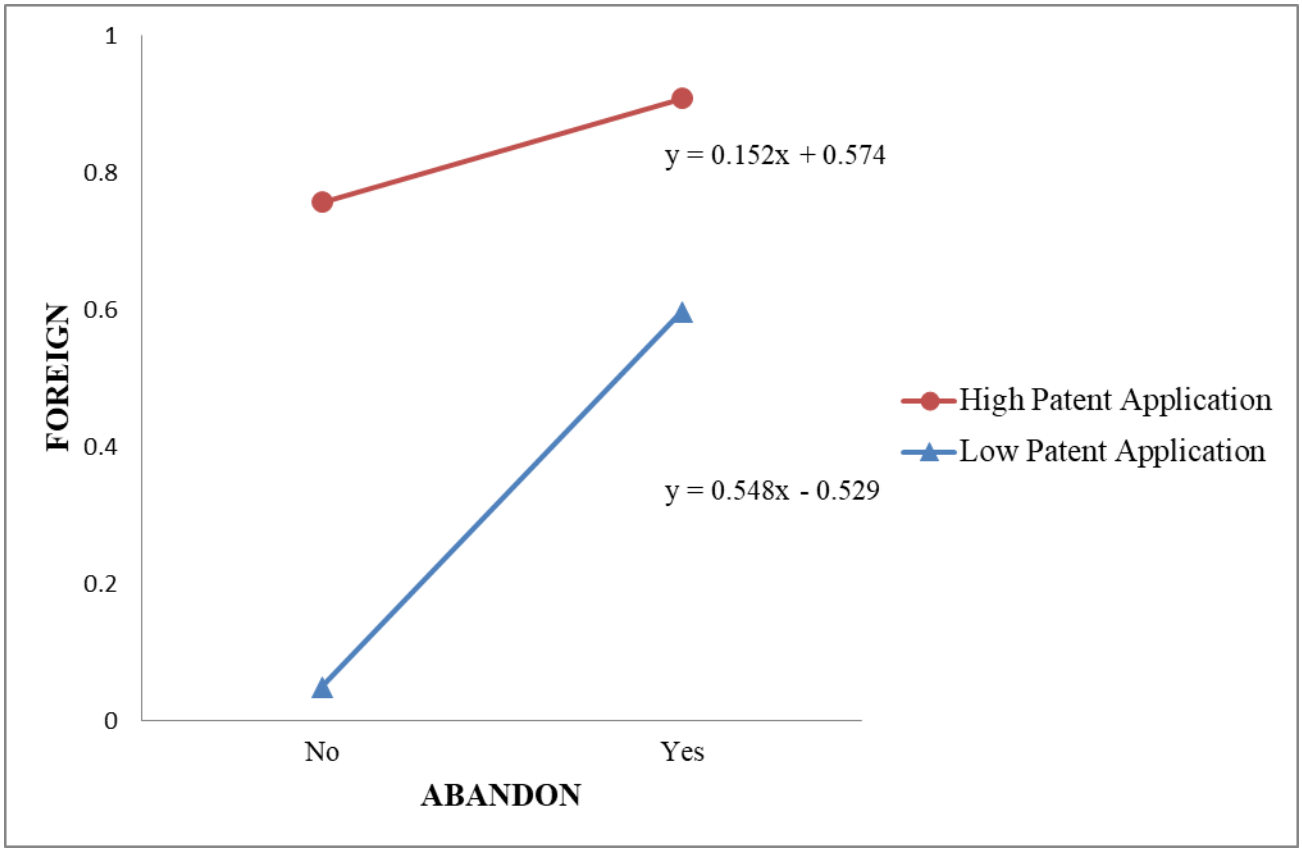


Figure 2. The moderating effect of patent applications on the relationship between experience of abandoning innovation projects (ABANDON) and foreign direct investment in R&D (FOREIGN)



Appendix 1

Some examples about disclosing innovation abandonment:

(1) *Companies raise capitals through the crowdfunding route must disclose abandoned innovation projects, especially in high-tech manufacturing industry. Such abandoned projects include prominent ones like the Lily Drone. The company announced its abandonment on the project and was bought by Mota Group, who turned the abandoned product into the Lily Next-Gen in 2017.*
   a. *https://www.theverge.com/2019/4/16/18308523/kickstater-indiegogo-crowdfund-gadget-never-shipped*
   b. *https://www.theverge.com/2017/9/4/16251654/lily-drone-back-mota-group-next-gen*

(2) *The abandonment of a nine-year internet balloon project Loon from a subsidiary of parent firm Alphabet has been announced publicly in 2021 due to the commercial viability proved to be riskier. It aimed to provide global internet access with a fleet of balloons floating on the edge of space to serve rural areas.*
   a. *https://techcrunch.com/2021/01/21/google-alphabet-is-shutting-down-loon-internet/*

(3) *Google has announced abandonment on many projects that had been developed for a few years, including Project Tango (2014-2018), iGoogle (2005-2013), Google Talk (2005-2017), Google Reader (2005-2013), etc. For example, Project Tango had been developed for 4 years then was abandoned, but its abandonment was followed by a similar product ARCore that overcomes Tango's disadvantages.*
   a. *https://www.androidauthority.com/failed-google-products-list-943812/*

(4) *Alphabet also publicly ended Makani in 2020, who they have been collaborating with Energy company Shell. This project tried to generate power using wind turbines attached to kites.*
   a. *https://techcrunch.com/2020/02/18/alphabet-takes-the-wind-out-of-its-makani-energy-kites/*

(5) *Uber abandons effort to develop own self-driving vehicle in 2020, however it transferred driverless car division to a Silicon Valley start-up Aurora, which attracts funding from Amazon and Sequoia Capital.*
   a. *https://www.ft.com/content/e55ce767-0ede-4096-aa3b-1d26671f3772*