Foreign Subsidiaries' Internal and External R&D Cooperation in South Korea: Explanatory Factors and Interaction

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Abstract

This paper analyses R&D cooperation strategies by foreign subsidiaries of MNEs located in South Korea. It differentiates between foreign subsidiaries with no R&D cooperation and those which favour internal or external R&D cooperation. Providing country-specific discussion in the context of South Korea, this enables comparison and contrast of the importance of innovation networks developed by MNE subsidiaries. Using various models, the results show that foreign subsidiaries in South Korea adopt complementary internal and external R&D cooperation strategies. Knowledge-sourcing is found to be a key determinant of R&D cooperation, and government policies act as a strong incentive for inter-firm collaboration.

Keywords: MNEs, Foreign Subsidiaries, R&D Cooperation, Knowledge Sourcing, Innovation Policy, South Korea

Introduction

In the international business literature, subsidiaries are now positioned as key players in knowledge creation by MNEs (Pearce, 1999: Meyer *et al*., 2011; Rugman *et al*., 2011). Nevertheless, ambiguities remain, particularly with relation to factors that promote knowledge creation at subsidiary level. Subsidiaries' engagement with external partners and its strategic significance for the development of subsidiary capabilities is widely acknowledged (Andersson et al., 2002; Almeida and Phene, 2004; Phene and Almeida, 2008). It is also established that subsidiaries will develop both external and internal technological relationships (Forsgren et al. 2005; Santangelo 2009; Yamin & Andersson 2011), so that one may not exclude the other. Yet we know little about the knowledge-creating activities that subsidiaries undertake *vis-à-vis* their network partners or potential partners. In particular, there is little evidence focusing on R&D collaboration by subsidiaries. R&D collaboration is important, because it captures the active role of subsidiaries in knowledge creation, and is a key means of knowledge access, creation and capture (Cantwell and Mudambi, 2005; Kappen, 2011).

Broader innovation studies have highlighted the rising importance of R&D cooperation in firms' innovative activities (Hagedoorn, 2002) and explored antecedents and drivers of such collaboration. However, these do not shed light on the multinationality context in which foreign subsidiaries reside. Similarly, the industrial organisation literature provides extant knowledge on external R&D cooperation. Studies point to various determinants for cooperation, some focusing on firm heterogeneity, such as internal R&D investment (or intensity) and size (Carboni, 2013; Cassiman and Veugelers, 2006; Fritsch and Lukas, 2001), while others focus on the outcome of R&D cooperation in terms of performance enhancement (Belderbos *et al*., 2004a). This stream of literature also emphasises the distinctive types of external cooperation (horizontal, vertical and institutional cooperation) (see, e.g., Belderbos *et al*., 2004b: Carboni, 2013). However, two main gaps remain: firstly, a focus on subsidiaries actively engaged in R&D cooperation, and therefore the need also to analyse internal R&D cooperation; and secondly, the relationship between internal and external cooperation. Understanding such a relationship matters, since Belderbos *et al*. (2004b) suggest there may be correlations and complementarities between different types of cooperation. Our study aims to address the above research gaps, firstly by focusing on foreign subsidiaries, secondly by taking into account the possible relationships between internal and external R&D cooperative strategies, and thirdly by exploring explanatory factors behind R&D cooperation.

The recent international management literature has pointed to the changing structure of MNEs (Hedlund and Rolander, 1990), moving away from the traditional model of a firm where knowledge transfer is unidirectional (from HQs to foreign subsidiaries), and emphasising the ability of subsidiaries to generate their own knowledge (Birkinshaw and Hood, 1998) and distinct technological competences (Cantwell and Mudambi, 2005), notably by adapting various technology-sourcing strategies (Manolopoulos *et al*., 2007, 2009; Pederson *et al*., 2011). MNEs increasingly locate R&D facilities close to leading centres of research and innovation, adopting international technology-sourcing strategies (Bartlett and Ghoshal, 1986; Pearce, 1999; Chung and Yeaple, 2008; Papanastassiou and Pearce, 2009). Initially, HQs retain a central position in determining the location of innovation, and assign specific roles to foreign subsidiaries. As subsidiaries build capabilities of knowledge creation or exploitation (Cantwell and Mudambi, 2005), the risks of external collaboration diminish and the benefits of internal collaboration will be greater.

Looking at a subsidiary's R&D cooperation activities presupposes an active role played by the subsidiary, which on the one hand brings valuable technological knowledge into the MNE, and on the other hand may *leak* this knowledge when engaging in R&D cooperation. By integrating both internal and external cooperation, our contribution is to help resolve some of the ambiguity in the subsidiary-innovation literature. However, potential risks and benefits of both internal and external R&D collaboration can only be grasped accurately by incorporating both subsidiaries' technological competencies and capabilities, and the potential technological richness of the host environment, as factors in the analysis.

This paper focuses on the context of South Korea, a dynamic Asian country in terms of innovation (Giroud and Tucci, 2012). Although South Korea (hereafter Korea) only recently liberalised its economy towards inward Foreign Direct Investment (FDI), it presents several features of interest for the study of foreign subsidiaries' R&D activities. The country has achieved technological development at an impressive speed and its local companies have become key global competitors (Hemmert, 2012). As a result, MNEs seeking international knowledge-sourcing find its country-specific assets attractive (Lee and Rugman, 2009). Inward FDI stock had increased from a mere US$5,186 million in 1990 to a staggering US$147,230 million by 2012 (UNCTAD, 2013). In 2010, Korea's domestic R&D expenditure as a percentage of GDP ranked third-highest amongst OECD countries (OECD, 2012). Industry is the dominant R&D actor in Korea, financing 71.8 per cent of all projects in 2010 (compared to 10.8 per cent for higher education and 12.7 per cent for government laboratories) and conducting 74.8 per cent of all R&D. In just a decade, industry-financed R&D has jumped from representing 1.66 per cent of GDP in 2000 to 2.68 per cent in 2010. As MNEs are increasingly present in Korea, they participate in the rise in industry R&D expenditure and Korea's current international success. It has been shown that foreign subsidiaries are more innovative than local firms (Castellani and Zanfei, 2006; Sadowski and Sadowski-Rasters, 2006) and contribute to the innovation performance of emerging markets (Wang and Kafouros, 2009). In Korea's case, enhanced national innovation is also the result of recent policy efforts by the government to strengthen its innovation policies. There is evidence in the literature that government innovation policy has positively influenced innovation activities by foreign subsidiaries in the manufacturing sector (Giroud *et al*., 2012). For this reason, we suggest it is also essential to investigate the influence of innovation policy on subsidiaries' R&D cooperation strategies.

The data used in this paper is pooled cross-sectional data from two waves of the Korean Innovation Survey (KIS), in 2002 and 2005. With a sample of up to 293 foreign subsidiaries in the Korean manufacturing sector, we construct a series of multinomial logistic models and simultaneous equation models by 3SLS. We differentiate between foreign subsidiaries with no R&D cooperation, subsidiaries which favour internal R&D cooperation, and subsidiaries which favour external R&D cooperation. We first analyse the relationship between internal and external R&D cooperation, before exploring key determinants – knowledge sources, subsidiary technological heterogeneity and government policy.

The remainder of this paper is structured as follows: The literature section develops theoretical considerations, hypotheses and the conceptual framework. The empirical analysis section provides details of the database, measurements used and modelling techniques. The empirical results section presents key findings from empirical models. The final section provides a discussion of the results, conclusions and suggestions for future research.

Theoretical Considerations, Hypotheses and Conceptual Framework

R&D cooperation

In this paper, R&D cooperation refers to various situations when a subsidiary interacts with one or more partner organisations to engage in joint R&D activities with a view to generating innovation, such as technological knowledge, products or processes (Nummela, 2003). R&D cooperation involves a degree of interdependence and interaction between partners (Narula and Hagedoorn, 1999), and partners make substantial contributions of resources and technological know-how (Tyler and Steensma, 1995). Internal R&D cooperation involves projects with other units in the same MNE, in the host economy or across borders (Gassman and von Zedtwitz, 2003; Yamin and Otto, 2004; Bergek and Bruzelius, 2010). External R&D cooperation involves projects with external business partners such as customers, suppliers, universities and research institutes (Belderbos *et al*, 2004; Carboni, 2013).

There are reasons why firms engage in R&D cooperation, including risk- and/or cost-sharing in uncertain technological environments, the pursuit of gains such as economies of scale and scope, the synergistic effects of pooling resources, monitoring of technological developments, or responding to government-subsidy policies (Belderbos *et al*, 2004:1479). From a transaction-cost perspective (Williamson, 1985), cooperation can decrease costs, because the firm controls and monitors knowledge transfer. From a resource-based view, cooperation contributes to a firm's knowledge base when partners combine resources and resource complementarities can be exploited. The issue of power and control over scarce resources is paramount (Pfeffer and Salancik, 1978).

From the international-management perspective, a foreign subsidiary's R&D cooperation strategies are influenced by its specific role, mandate and position within the MNE network (Bartlett and Ghoshal, 1986; White and Poynter, 1990; Birkinshaw and Hood, 1998). MNEs increasingly locate R&D facilities close to leading centres of research and innovation, with internationally-dispersed technology units that remain linked to corporate-level R&D networks (Pearce, 1989, 1999), and carefully-designed key roles for decentralised R&D centres in the technological and competitive evolution of the firm (Papanastassiou and Pearce, 2009). R&D units represent a means to get close to where knowledge is produced and gain access to competitive assets through external technological networks (Veugelers and Cassiman, 2004; Meyer *et al*, 2011). MNEs then find it advantageous to create interdependencies and encourage cross-border collaboration amongst various units

(Papanastassiou and Pearce, 2009; Mudambi *et al*, 2007), notably to facilitate knowledge-sharing (Almeida and Phene, 2004; Najafi-Tavani *et al*., 2012; Yamin and Otto, 2004).

R&D requires heavy investment and plays a significant role in a firm's ability to sustain its technological advantages in hyper-competitive markets. This affects R&D cooperation decisions, as they result from a complex process of mitigating risks and minimising costs, a process that is even more complex in the context of foreign subsidiaries.

External R&D cooperation can: favour the exploration of resource and capability in the host environment (Narula and Dunning, 2010), for instance in terms of new product development (Andersson *et al*., 2002); potentially improve the strategic positioning of the subsidiary within the MNE (Forsgren *et al*., 2005); lower the uncertainty of external technology acquisition in cases of information asymmetries in the market, or successful combination of internal and external knowledge (Teece, 1977; Alcácer and Chung, 2007); or improve performance (Figueiredo, 2011; Pedersen *et al*., 2011). On the other hand, it can be perceived as entailing risks such as non-pecuniary technological externalities, knowledge leakage to potential competitors or loss of technological superiority (Birkinshaw and Fey, 2003; Mudambi and Navarra, 2004; de Faria and Sofka, 2010), as well as costs related to knowledge transfer, monitoring or learning (Teece, 1977).

Similarly, subsidiaries' internal R&D collaboration within the MNE offers benefits, e.g. increased internal visibility for the subsidiary, and the resource-based view of the firm suggests internal cooperation is easier (Kogut and Zander, 1993); however, such co-operation is likely to have a lower exploratory dimension and will be more concerned with combining and developing knowledge along the MNE's existing trajectory (Yamin and Andersson, 2011). Internal R&D collaboration may thus entail lower risks, but also lower potential benefits for the MNE as a whole, leading subsidiaries to consider trade-offs of both types of cooperation and engage in multiple internal and external cooperation (Cassiman and Veugelers, 2006).

In its drive to support the MNE in generating new or adapting existing products, a subsidiary is likely to engage in dual modes of R&D cooperation. Through creative individualism, some subsidiaries develop particular areas of distinctive knowledge competence (we refer to this as technological heterogeneity), which in turn will affect their position within R&D networks, within the MNE and externally in the host economy (Pearce and Papanastassiou, 1996; Pearce, 1999; Papanastassiou and Pearce, 2009). The literature has discussed how far a firm can favour external cooperation strategy, but has not unravelled how a subsidiary simultaneously chooses between different modes of R&D cooperation.

R&D cooperation in the context of Korea

The nature and position of R&D activities performed by MNEs in Korea is important for a number of reasons. Firstly, FDI inflows have increased significantly over the past two decades. Liberalisation efforts in the late 1990s were perceived by the government as a way of addressing the currency crisis, strengthening the competitive advantage of Korea's industry, and boosting technology transfer to improve the competitiveness and efficiency of local firms (i.e. enhancing positive FDI effects, as sectors with FDI have higher-than-average labour productivity, wages and R&D expenditures) (Nicolas *et al*., 2013). Secondly, local Korean firms have upgraded their technological competencies, many firms becoming world leaders (Hemmert, 2012), and they play a key role in the country's technological dynamism, as exemplified by the fact that more than two-thirds of R&D is conducted by industry (OECD, 2012). However, much of this R&D remains highly concentrated amongst a small number of large global firms, mostly within family-owned business groups or *chaebols* (Bartzokas, 2008), so in the context of inter-firm R&D cooperation, foreign MNEs may be hesitant in sharing key technology with competitors. Thirdly, the Korean government plays an active role in the economy. The nature of this role has changed since the Asian crisis, and Korea is now described as a reconfiguring developmental state (Witt, 2013; Witt and Redding, 2013) that actively promotes R&D through its National Innovation Strategy, and is shifting from a catch-up approach to an emphasis on private-enterprise technology development and networking amongst key players. OECD's micro-innovation data shows that in 2005 16.9 per cent of Korean firms surveyed conducted formal collaborative R&D, slightly above the average of fifteen OECD countries surveyed (OECD, 2009). In the meantime, the intellectual property rights (IPR) regime is relatively weak, and IPR protection is a key factor determining a firm's innovation-strategy profile (OECD, 2009); in combination with a highly competitive market environment, this points to the possible exposure of foreign firms to knowledge leakage.

To summarise, local Korean firms have become good potential cooperative partners for R&D projects with foreign subsidiaries located in Korea. On the other hand, the risk of losing core technology may influence R&D cooperation strategies of MNEs in the country, even though R&D cooperation may be positively influenced by the recent NIS objective of encouraging inter-firm technological collaboration.

The relationship between internal and external R&D cooperation

At the subsidiary level, multiple embeddedness confers specific advantages in terms of technological capabilities, as not only do subsidiaries possess their own technological competences, but they can develop those further through external technological networks in host countries (Pearce, 1999; Almeida and Phene, 2004; Belderbos *et al*., 2006; Yamin and Otto, 2004), internal technological networks (Gupta and Govindarajan, 2000; Gassman and von Zedtwitz, 2003; Pedersen *et al*., 2011), or both (Figueiredo, 2011; Narula and Dunning, 2010; Meyer *et al*., 2011). The distinction between internal and external R&D cooperation strategies is not straightforward, since both can co-exist, reflecting dynamic interdependence and complementarity (Belderbos *et al*., 2004; Castellani and Zanfei, 2006).

Given the distinctive capabilities of MNEs in mobilising and reconfiguring knowledge across MNE organisational boundaries and networks (Foss and Dos Santos, 2011; Phene and Almeida, 2008), subsidiary external collaborations could benefit MNE technological development as a whole and encourage lateral knowledge transfer in MNEs (Yamin and Andersson, 2011). Thus, internal R&D cooperation increases the MNE's exploration potential and stimulates the search for new knowledge outside the MNE, which in turn may lead to external cooperation by subsidiaries to absorb new knowledge (Castellani and Zanfei, 2006). Internal cooperation also raises the subsidiary's corporate visibility and that of its externally-generated knowledge. In this case, internal and external cooperation are complementary in generating organisational importance for the subsidiary.

In the specific case of Korea, the level of technological competencies of local business partners means that R&D cooperation by subsidiaries is likely to be strategically significant due to spillover-related competitive implications (we may thus expect that HQs will likely monitor and exert influence in the direction of subsidiary R&D cooperation). Despite the higher risk of technology leakage, we suggest that external collaborations can benefit a subsidiary's technological development and that of the MNE as a whole, if the firm can use one strategy to mitigate risk arising from another strategy. Overall, we suggest that the relationship between internal and external cooperation of foreign subsidiaries in Korea is interdependent and complementary. Thus:

> **Hypothesis 1** In South Korea, the relationship between internal and external cooperation of foreign subsidiaries is complementary.

Factors explaining R&D cooperation

Knowledge-sourcing. Knowledge-sourcing refers to a subsidiary’s access and use of knowledge and technologies, internally from the headquarters or other units of the MNE or externally from public or private sources of knowledge (e.g. public research institutions, or local firms such as customers, suppliers, competitors, universities, local research centres) (Chung and Yeaple, 2008; Manopoulos *et al*., 2009; Pedersen *et al*., 2011). Following Veugelers (1997) and Vega-Jurado *et al*. (2009), we differentiate bought-in knowledge (*knowledge-sourcing*) from cooperation, which also constitutes a means to acquire knowledge.

Internal knowledge-sourcing facilitates a subsidiary's involvement in cross-border intra-MNE innovative activities (Pearce, 1999; Yamin and Andersson, 2011), and although the degree to which internal knowledge-sourcing depends upon the type of subsidiary and R&D activities, we expect a positive relationship between internal knowledge-sourcing and internal R&D cooperation. On the other hand, while some degree of internal knowledge-sourcing may be necessary for certain types of external R&D cooperation, we expect that subsidiaries engaged in external R&D cooperation may be cautious about unintended knowledge spillovers, especially in a technologically-dynamic environment such as Korea, and for this reason we do not anticipate internal knowledge-sourcing to be related to external R&D cooperation.

Evolving dynamic capabilities and R&D cooperation depend on a subsidiary's embeddedness in the external environment, which enhances physical proximity with local knowledge sources and familiarity with business networks (Andersson *et al*., 2001; Forsgren *et al*., 2005; Phene and Almeida, 2008). Where, as in Korea, the technological capabilities of local business partners are high, there may be an incentive for subsidiaries to engage in external R&D cooperation, both to enhance their own knowledge development and to enable them to manage the risks entailed of spillovers of internally-sourced knowledge to external counterparts. In addition, given the dominance of corporate R&D in the Korean innovation system (OECD, 2012), external industrial-knowledge sources are expected to be as important as external scientific-knowledge sources in facilitating R&D cooperation. Thus, overall, external knowledge-sourcing facilitates both internal and external R&D cooperation,

Hypothesis 2 In South Korea, external knowledge-sourcing is positively related to both the subsidiary's external and internal R&D cooperation, but internal knowledge-sourcing is only positively related to internal R&D cooperation.

Subsidiary Technological Heterogeneity. Recent studies on knowledge flows within MNEs suggest that they are dependent upon the strategic position and relative performance of the subsidiary (Andersson *et al.*, 2007). This would take into consideration both the subsidiary's technological capacity and its innovation-strategic orientation. The subsidiary's R&D intensity is generally viewed as an indicator of innovation performance (Kafouros, 2008), because R&D capacity contributes to innovation and knowledge creation, and forms the basis for absorptive capacity (Cohen and Levinthal, 1990), thereby increasing the potential for absorption of knowledge sourced internally or externally (Phene and Almeida, 2008). This is one reason why MNEs are more inclined to locate R&D facilities near centres of research and innovation (Ito and Wakasugi, 2007). The subsidiary's absorptive capacity facilitates a two-way flow of technology, from HQ to subsidiary and *vice versa*, and from external business partners to the subsidiary (Giroud, 2012; Santangelo, 2009). With respect to R&D cooperation, Tether (2002, using UK CIS data) and Fritsch and Lukas (2001) have found a positive relationship between R&D intensity and external cooperation. Although these studies did not focus on MNEs, we expect to find similar results. Thus, we suggest:

Hypothesis 3a R&D intensity is positively related to a subsidiary's internal and external R&D cooperation.

With the rise of MNEs as differentiated networks, with activities carefully located in appropriate locations worldwide (Buckley, 2009; Meyer *et al*., 2011; Rugman *et al*., 2011), individual subsidiaries not only act as knowledge harvesters, but also as key knowledge initiators. A subsidiary's innovation orientation influences its innovation activities, decisions and performance (Kafouros, 2008; Wang and Kafouros, 2009), and ultimately its position within the MNE network (Andersson *et al*., 2007; Mudambi and Navarra, 2004). Innovation may involve either exploitation of existing competences or exploration of new competences (March, 1991), and within the international-management literature, a distinction occurs between competence-creating subsidiaries (those with the ability to develop new products and expand to new markets by drawing on new capabilities) and competence-exploiting subsidiaries (those involved in cost reduction and quality improvement by using existing capabilities) (Cantwell and Mudambi, 2005). Competence-creating subsidiaries are likely to have greater in-house knowledge-creating capabilities compared to competence-exploiting subsidiaries. However, we also expect the former to have greater combinative and sourcing capabilities than the latter (Phene and Almeida, 2008), On this basis, we expect:

Hypothesis 3b Competence-creating subsidiaries engage more in internal and external R&D cooperation than competence-exploiting subsidiaries.

Government Innovation Policy. Korea has recently engaged in active innovation policies after experiencing a decrease in corporate R&D spending following the Asian financial crisis. In response, the government increased public R&D budgets, promoted the development of a technology-based SME sector, and implemented targeted measures such as facilitating venture start-ups and growth, providing finance (through funds and tax incentives) and research support (R&D funding, tax waivers, tariff exemptions for R&D equipment) (OECD, 2009). These measures have been successful, with numerous R&D labs opening throughout the country, yet there are no studies investigating their specific impact on foreign firms' innovation activities. Whilst previous studies on R&D cooperation determinants have not focused on innovation policy, studies do acknowledge the importance of *institutional cooperation* as part of external R&D cooperation (Belderbos *et al*., 2004). For host-country governments, attracting and promoting R&D by subsidiaries located within their national borders matters, because the entry of innovative FDI will generate social advantages for local industries in the form of knowledge spillovers (Casson, 2007:308). Cantwell and Mudambi (2000:142) find that long-term measures under the umbrella of a country's national innovation system are likely to be effective in terms of supporting innovatory activities in subsidiaries. This was confirmed in the case of Korea, where selected local-government initiatives have a positive effect on subsidiaries' innovation (Giroud *et al*., 2012). In the case of the Korean hydrogen-energy sector, Choi *et al*. (2011) found that the government facilitates network collaboration amongst various actors. Given that Korea's innovation policies focus on prompting local innovative activities and inter-firm collaboration, these are unlikely to influence an MNE's decision regarding internal R&D cooperation, but are more likely to facilitate external R&D cooperation by subsidiaries with external technological partners (public or private). For these reasons, we suggest that:

Hypothesis 4 In South Korea, government innovation policy is positively related to subsidiaries' external R&D cooperation.

Empirical Analysis

Data

The goal of this empirical analysis section is to examine the determinants of different types of R&D cooperation strategy adopted by foreign subsidiaries. We exploit firm-level data collected through the Korean Innovation Survey (KIS). This survey follows the OECD's Oslo manual, which provides a harmonised framework for nationwide surveys about firms' innovation activities. A designated government office conducts the survey every three years, targeting firms in the manufacturing sector, and the data covers the previous three-year period. The population is identical to that of the national manufacturing survey.

Our data are based on two survey waves, conducted in 2002 (KIS, 2002) and 2005 (KIS, 2005). From the same sample as the national manufacturing survey, a total of 3,775 and 2,774 companies responded in 2002 and 2005 respectively. The pooled data includes 423 foreign subsidiaries. From this we identified a sub-sample of foreign subsidiaries by singling out firms with a foreign ownership ratio of at least 50%. Using this criterion, our sample comprises 293 foreign subsidiaries, drawn from pooled cross-sectional data. In compiling the final dataset, we removed any repeated respondents, to prevent bias in our estimation results.

Dependent variables

The dependent variables are drawn from questions relating to R&D cooperation strategy type in the survey. Following earlier studies (Fritsch and Lukas, 2001; Belderbos *et al*, 2004; Cassiman and Veugelers, 2006), external R&D cooperation is measured by the extent of the subsidiary's cooperation with external public and private partners in Korea, i.e. materials suppliers, software suppliers, customers, competitors, new employees, non-profit organisations, public and private research centres, universities, and business-service agencies. The responses are recorded using a six-point Likert scale (0=not applicable, 1=not important, 5=very important). Internal R&D cooperation is measured by the extent to which the subsidiary cooperates with other intra-MNE units (Gassman and von Zedtwitz, 2003; Yamin and Otto, 2004; Bergek and Bruzelius, 2010). We created three sub-categories, as defined below:

- Cooperation type 1: Foreign subsidiaries that do not engage in R&D cooperation (a score of 0 was given to all R&D cooperation questions).

- Cooperation type 2: Foreign subsidiaries actively engaged in internal R&D cooperation with other units of the MNE (internal cooperation score is greater than zero, and equal or higher than the average score of external R&D cooperation, so that internal>=external).
- Cooperation type 3: Foreign subsidiaries actively engaged in external R&D cooperation (external cooperation score is greater than 0 and greater than that of internal cooperation, so that external>internal).

In the data, we identify each category by assigning zero to Type 1, one to Type 2, and two to Type 3. For a robustness check, we use a reduced sample of firms. Firms that favour Internal or External R&D Strategies but apply more of a balanced approach to R&D Cooperation (that is, they engage in equal or similar levels of Internal and External Cooperation) are removed from the sample. A balanced approach is defined as firms whose score difference between external and internal R&D cooperation is within half of the standard deviation from the zero point in the distribution of the score difference. Eighteen firms are considered to take a balanced approach (three previously in Type 2, and fifteen Type 3), and are removed in a reduced sample used for additional testing.

Independent variables

Independent variables are measured using multi-item questions. Firstly, a factor analysis is conducted to identify latent components in the initial pooled cross-sectional data. Secondly, factor scores for concerned components are generated for each firm. The process of variable specification is explained below.

*** Place Table 1 Here ***

- Knowledge-sourcing: following previous studies (Chung and Yeaple, 2008; Manolopoulos *et al*., 2009; Pedersen *et al*., 2011; Veugelers, 1997; Vega-Jurado *et al*., 2009), knowledge-sourcing is measured by the extent to which a subsidiary acquires knowledge externally from suppliers (distinguishing between materials and software suppliers), customers, competitors, new employees, non-profit organisations, public research centres, private research centres, universities, business services agencies, or internally from intra-MNE units. Respondents answered the importance of each source of knowledge for the subsidiary, using a six-point Likert scale (0=not applicable, 1=not important, 5=very important). Further details on knowledge-sourcing variables can be found in Table A1. Based on the factor analysis and components extracted, we consider three types of knowledge source, namely: Knowledge-sourcing 1 (focusing on external scientific information), Knowledge-sourcing 2 (focusing on external industrial information), and Knowledge-sourcing 3 (information obtained internally from other MNE units). The three components together account for 82.086 per cent of the total variance in the question.
- Subsidiary technological heterogeneity (1): Subsidiary technological heterogeneity is measured in terms of subsidiary internal resources. Subsidiary-level internal resources indicate the firm's ability to access external sources of knowledge and information. Following Vega-Jurado *et al*. (2009), we compute the proxy for R&D intensity by dividing a firm's R&D expenditure by its sales volume.
- Subsidiary technological heterogeneity (2): The second measure of subsidiary technological heterogeneity is type of technological activity, and whether a

subsidiary creates or exploits competences. While some studies identify competence-creating subsidiaries in terms of output of technological activities (Marin and Sasidharan, 2010), most use self-reported information in order to identify the existence of technological activities relating to purchasing, production, marketing, logistics and distribution activities (Asmussen *et al*., 2008; Cantwell and Mudambi, 2005; Kappen, 2011). We follow the latter approach. For this effect, we use a series of ten questions related to objectives of innovation activities, based on a six-point Likert scale (0=not applicable, 1=not important, 5=very important). We conduct a factor analysis and with the interpretability criterion (as literature expects two factors) and total variance criterion (as two factors account for over 80 per cent of total variance), extract two components, with the cumulative sum of loadings being 83.998 per cent (see Table A2). The first component is closely associated with activities exploiting existing competences; we name it *Competence-exploiting subsidiaries*. The second component represents competence-creating innovation, with high loadings for activities such as product diversification, new product introduction and market-power expansion; we name it *Competence-creating subsidiaries.*

- Government policies: We assess the role of government policy using questions about the effectiveness of innovation-policy instruments. Managers were asked to evaluate the effectiveness of government policy with regards to 1) Training, 2) Information service, 3) Technical support, 4) Public project opportunities, 5) Financing, and 6) Tax. This is measured on a six-point Likert scale, with zero for ‘Not applicable’. Similarly to Mudambi and Mudambi (2005), we conduct a factor analysis to aggregate data from the six policy items. We find three components (with a cumulative loading of 74.519 per cent): *Policy 1* (policies supporting firms' sourcing and exploration activities), *Policy 2* (policies facilitating firms' exploitation and commercialisation of innovation output), and *Policy 3* (tax benefits) (see Table A3).

- Control variables: We use four control variables, namely foreign-ownership ratio (see Table A4), age, technology type and a year dummy. Foreign-ownership ratio provides insights into the strategy undertaken by the MNE in response to risk, uncertainty, outsider liabilities and other adverse conditions of the external environment in the host country. Age is related to the degree of resource commitment as a result of learning in the local market. For technology type, as suggested by the OECD, we establish five types, separating industries by NACE 2-digit classification in terms of sophistication of technology, as shown in Table 1. We use technology type 1 and year 2002 as reference.

The correlation analysis (see Table A5) does not show any close correlation amongst variables. Finally, all data come from a single source partly based on respondents' subjectivity, and therefore may exaggerate internal consistency, causing common method bias (CMB) (Chang *et al*., 2010). In the first place, we considered Harman's one-factor test and the marker test for detection and reduction of potential CMB (e.g. Podsakoff *et al*., 2003). However, there is limited established procedure in the literature for non-linear regression models such as ours, and there is no guarantee that either test will treat CMB successfully (Richardson *et al*., 2009). We analyse the data through a three-stage least-square model and the non-linear multinomial logistic model, which involve reasonably complex specifications and thus diminish the model's exposure to common method variance (Chang *et al*., 2010).

Model and estimation methods

Hypothesis 1 refers to the relationship between Type 2 and Type 3 strategies. Hypotheses 2, 3 and 4 refer to the determinants of different R&D cooperation strategies. Our empirical test is based on two models.

First, a simultaneous equation model by three-stage least square is estimated to test Hypothesis 1. Hypothesis 1 predicts that Type 2 and Type 3 of cooperation strategy by the i^{th} firm can be endogenous variables that are determined by one another within the same system. We scrutinise relationships between two simultaneously-correlated endogenous variables by using the simultaneous equation model, comprising two regression models. When two dependent variables simultaneously determine each other, this means that two regression models are connected through error terms and common explanatory variables. However, equations should not be identical, and thus each regression contains a few unique exogenous variables (Gujarati, 2003). Therefore, we identify each equation by assuming that *Subsidiary technological heterogeneity* and *Policy* are the common explanatory variables, while the three *Knowledge-sourcing* variables act as exogenous variables. Additionally, we enter the control variables identified. As a result, our model is summarised as follows:

Internal cooperation $_i = f_1$ (External cooperation $_i$, **Knowledge sourcing (3)** $_i$, **Subsidiary heterogeneity** $_i$, **Policy** $_i$, **Control** $_i$) (1)

External cooperation $_i = f_2$ (Internal cooperation $_i$, **Knowledge sourcing (1 & 2)**$_i$, **Subsidiary heterogeneity** $_i$, **Policy** $_i$, **Control** $_i$) (2)

The estimation of the model assumes three stages: firstly, each endogenous variable is instrumented by unique exogenous variables. Secondly, the predicted values will replace the endogenous variables in the subsequent equation. Finally, the equations are adjusted based on the cross-equation covariance matrix.

Secondly, multinomial logistic regressions are used to test Hypotheses 2, 3 and 4 about R&D cooperation determinants. Our dependent variable takes three values: 0, 1, and 2, representing the three mutually-exclusive types of cooperation strategy (Types 1, 2 and 3 respectively). The regression shows the impact of each explanatory variable on the probability that the firm may undertake one cooperation strategy relative to the base outcome. Type 1 strategy (no R&D cooperation) is our base outcome, in that we expect a firm will take a sequential approach, from no R&D cooperation to internal cooperation, or from no cooperation to external cooperation. Coefficients in the model therefore demonstrate the role of each explanatory variable in determining the probability of the firm's decision to favour internal or external R&D cooperation relative to having no R&D cooperation at all. Models 1 to 4 use the full sample, Model 5 uses the reduced sample.

Pr (Cooperation type $_i$) = f_3 (**Knowledge sourcing** $_i$, **Subsidiary heterogeneity** $_i$, **Policy** $_i$, **Control** $_i$), where Cooperation type = 0,1, and 2 and the base outcome is 0. (3)

Our sample is composed of 156 majority foreign-owned international joint ventures (IJV) and 137 wholly-owned subsidiaries (WOS) (see Table A-4). Overall, 72.7 per cent of foreign subsidiaries do not engage in R&D cooperation, 16.7 per cent favour internal R&D cooperation strategy and 10.6 per cent favour external R&D cooperation strategy. WOS tend to be less engaged in R&D cooperation, and when they are, it is mostly in terms of internal R&D cooperation (20 WOS favour internal R&D cooperation, 8 for external). This result is consistent with extant knowledge that a WOS is suitable for FDI requiring a greater level of control by HQ and the need for knowledge protection of valuable intangible MNE-level technology (Brouthers and Hennart, 2007). IJVs equally favour one or the other types of cooperation (29 cases for internal and 23 for external R&D cooperation).

Empirical Results

The relationship between internal and external R&D cooperation

Hypothesis 1 is about the simultaneous interaction between internal and external R&D cooperation strategy. Table 2 shows a stack of two equations estimated as the 3SLS model simultaneously, where coefficients for both external (Equation 1) and internal R&D cooperation (Equation 2) are positive and statistically significant. This shows that there are mutually-reinforcing relationships between the importance of R&D cooperation with intra-MNE partners and the importance of R&D cooperation with external partners in our dataset. Therefore, Hypothesis 1 is accepted.

** Place Table 2 here **

Determinants of R&D cooperation

The multinomial logistic regression Models 1-5 are presented in Table 3. Key independent variables are inserted to test matching hypotheses. The full model includes all key independent variables, and shows the highest goodness-of-fit. In terms of the determinants of the type of R&D cooperation strategy, we refer to the upper part of the table, 'Type 2 - Internal R&D cooperation – strategy'; whilst the lower part of the table is about 'Type 3 - External R&D cooperation – strategy'. Hypothesis-testing is based on the coefficient of key drivers of the R&D cooperation strategy type, with the effect of the specific entry strategy by the subsidiary in response to the overall external task environment being reduced, as our sample comprises majority IJV or WOS, excluding minority IJV. We find consistent and robust findings in terms of the sign of coefficient observed across Table 2's 3SLS model and

Table 3's multinomial models, discussed below.

** Place Table 3 Here **

Hypothesis 2 explores the role of three types of knowledge-sourcing as a determinant of R&D cooperation. In both upper and lower equations in Models 1, 4 and 5 (see Table 3), the coefficient of external knowledge source 1 is positive and statistically significant; in the lower equations, that of external knowledge source 2. This means high reliance on external local-knowledge sources increases the likelihood for a firm to engage in internal and external R&D cooperation. This finding supports the theory of MNE networks, by sourcing knowledge externally, subsidiaries not only gain access to valuable knowledge, but also develop crucial networks that will enable them to identify potential cooperation partners and enhance their ability to productively cooperate with them.

By contrast, our results demonstrate the cautious attitude of foreign subsidiaries with regard to internal knowledge-sourcing. Internal knowledge-sourcing is positively related to internal R&D cooperation, but negatively (and statistically significantly) related to external R&D cooperation in Korea (in this case, it is negative and statistically significant). This may indicate that foreign subsidiaries in Korea are cautious about the potential for unwanted leakage of technology resulting from external R&D cooperation. Hypothesis 2 is accepted, Knowledge Sourcing act as a key determinant for R&D Cooperation.

Hypothesis 3 is about the effect of subsidiary technological heterogeneity; specifically, a subsidiary's internal resources and technological activity type. A subsidiary's R&D intensity is not statistically significant for either internal or external R&D cooperation; thus, Hypothesis 3a is not confirmed. This contrasts with the results of previous studies that have shown a positive relationship between investment in R&D and R&D cooperation (Belderbos *et al*., 2004; Carboni, 2013; Fritsch and Lukas, 2001). The fact that the role of subsidiary-level capability is not supported may indirectly reflect the more complex interaction between subsidiary-level actors and locational factors: for instance, firms with high R&D intensity may experience higher potential risks arising from external R&D cooperation. This could be the case in Korea, where market competition is fierce and the IPR regime weak compared to countries of similar levels of development in the region (e.g. Singapore, Taiwan) (World Economic Forum, 2013). In this situation, the MNE may favour an R&D cooperation strategy involving greater HQ supervision, or choose an equity-based mode of R&D, with greater control over knowledge assets, rather than a non-equity-based mode.

The results also show that CC and CE innovation are not statistically significant for both internal and external R&D cooperation. This indicates that both competence-creating and competence-exploiting activities in the MNE subsidiary are more strongly linked to internal R&D activities within the subsidiary than to R&D cooperation. Hypothesis 3b is not confirmed. The ambiguous effect of the type of technological activity in a subsidiary may indicate that the selection of R&D cooperation strategy is related to the type of R&D, such as, for instance, whether they focus on new product development activities.

Finally, our Hypothesis 4 concerns the effect of government policy. Models 3, 4, and 5 consider a situation where a firm makes strategic decisions in the light of innovation policy supports by the host-country government. Policies 1, 2 and 3 have a significant influence on external R&D cooperation, and as expected they do not act as determinants for internal cooperation. In other words, the host country's policy towards innovation can be an effective means for promoting technological collaboration between foreign subsidiaries and local business partners and research institutions. Hypothesis 4 is confirmed. This suggests that Korean innovation policy supports incoming spillovers from MNE subsidiaries to local external partners.

Discussion and conclusions

Our paper contributes to the growing literature within international management investigating the challenges of knowledge dispersion globally (Foss and Dos Santos, 2011; Gupta and Govindarajan, 2000). Importantly, it draws attention to the uniqueness of foreign subsidiaries in terms of R&D cooperation, particularly because innovation activities conducted by these firms are intrinsically related to overall MNE competitiveness, and various risks and interests are to be considered. A key contribution lies in analysing the unique conditions under which foreign subsidiaries located in Korea will engage in internal and external R&D cooperation.

Our results confirm that in Korea, the majority of foreign subsidiaries do not engage in any type of R&D cooperation, but when they do, Internal and External R&D Cooperation strategies are interdependent and complementary, and R&D Cooperation choices are very strategic.

This finding can be interpreted in the light of traditional MNE literature and the local country-specificity of Korea. Firstly, the foreign subsidiary in dynamic and technologically-advanced economies like Korea can act as a means to augment knowledge and access locational advantages (Dunning and Lundan, 2008; Meyer *et al.*, 2011). This would occur through a combination of local knowledge-sourcing – as a by-product of subsidiary transactions with (mostly) the private sector in Korea – as well as through external R&D cooperation. One could conclude from our study that MNEs located in Korea achieve their knowledge objectives (Gupta and Govindarajan, 2000), inasmuch as external knowledge (both private and public) sources are both positively related to internal R&D cooperation. Our models also show that foreign subsidiaries adopt complementary internal and external R&D cooperation.

Secondly, the parent company retains a central position in strategic decisions related to technological development (Ambos and Schlegelmilch, 2007; Ciabuschi *et al*., 2012). More pointedly, it may well be the case that the HQs see internal cooperation as a strategic tool to enhance MNE-wide knowledge absorption (or 'inward spillovers') from the local environment. Hence, whilst technological competencies of local firms and government policies can act as an impetus for external cooperation or a subsidiary's own technological activities (Giroud *et al*., 2012), MNE-related considerations dominate in the decision to engage in internal R&D cooperation. Even in a modern MNE, perceived as an entity in which individual units have a distinct ability to contribute knowledge to the network, such dependence can be related to the governance costs inherent in R&D cooperation. MNEs can draw enhanced benefit from the knowledge acquired by a subsidiary through internal R&D cooperation, which minimises the direct cost of transferring knowledge and acts as an incentive for knowledge transfer. In parallel, our results confirm that Korean firms are perceived as potential competitors by MNEs located in the country, as the latter remain cautious about knowledge leakage and potential unintentional spillovers, and protect their own knowledge. Indeed, external R&D cooperation is negatively related to internal knowledge-sourcing, while both types of knowledge-sourcing matter to internal R&D cooperation.

Our results contrast with existing studies implicating a subsidiary's technological competences in explaining cooperation – studies by Tether (2002), Fritsch and Lukas (2001) and Belderbos *et al*. (2004a) find that cooperating firms are more R&D-intensive – since R&D intensity does not explain the tendency to engage in external or internal cooperation. This points to the possibility that unobserved factors in the model, such as the intervention of MNE-level strategy and HQ-driven innovation, prevail in strategic decisions with regards to innovation cooperation. Alternatively, it is possible that subsidiaries' own technological competences matter, but as moderators (though this is not assessed in our models). This can be exemplified by the role of external knowledge. In order to realise its full potential, external knowledge needs to be transformed and internalised, which happens when combined with existing knowledge (absorptive capacity) or new internally-generated knowledge (Pederson *et al*., 2011).

Finally, a final major contribution in our model is to demonstrate the role of host-government policies in incentivising technology spillovers. Government policies are significantly linked to external R&D cooperation. This confirms that more targeted policies are more likely to lead to enhanced benefit from MNE activities in host economies (UNCTAD, 2013). In the case of Korea, previous studies have shown that innovation policy facilitates innovation activities by foreign subsidiaries; our paper provides new insights into the usefulness of innovation policies (even though they are not directly aimed at foreign subsidiaries) in facilitating cooperation with local partners. This is a significant finding that supports other reports demonstrating the positive role played by the government in Korea's technological development (Nicolas *et al*., 2013).

As all studies, it suffers from some key limitations. First of all, using a single source involves the risk of potential common-method bias, although tests show such risks should be negligible. While the data is rich and reveals detailed R&D strategy, it is based on subjective responses from individual firms' representatives, potentially raising concerns about validity of measurement, unless subjective information is carefully cross-checked with objective data or comparable previous studies. The focus on Korea as a case-study country may limit generalisability. Although most findings are consistent with theoretical discussions, some notable country-specific effects were highlighted in our results. Further, this research considers host-country factors and subsidiary-level factors, excluding variances potentially caused by MNE-wide strategic considerations and organisational dynamics.

To overcome such limitations, further research could build a larger sample of firms with

R&D cooperation, preferably across countries, to better explore the role of host-country factors, and distinguish between a number of R&D cooperation strategies. The inclusion of additional firm-level strategy variables, notably subsidiary role and position within the MNE network, should also be considered, and may be more easily conducted through a series of case studies on selected firms.

To conclude, the central contribution of our paper is to demonstrate how strategic R&D cooperation decisions made by MNEs located in Korea are. We have demonstrated that local Korean firms are perceived as strong potential competitors by MNEs, and therefore foreign firms in Korea need to balance internal and external R&D cooperative strategies carefully.

Our results therefore point to further unanswered questions requiring consideration, especially in terms of further exploring country-level characteristics that influence the technological considerations of MNEs. Amongst these, reports suggest that a substantial share of R&D activities in Korea is conducted by a small number of large firms. Our data does not allow distinction between types of R&D cooperation partners, but point to the need to better understand the dynamics of inter-firm cooperation in Korea. Namely, a distinction between the types of key actors involved in R&D would provide additional insights – not just in terms of size, but also in terms of governance structures (Yoo and Rhee, 2013) – as well as local firms' attitudes towards internal and external technological networking (Ryoo, 2012). Secondly, our results also show that both private and public external sources of knowledge positively influence R&D cooperation in MNEs. Future research should therefore question whether foreign firms also cooperate with public-sector institutions locally and under what circumstances. Thirdly, we have also pointed to the success of the Korean government's innovation policy in explaining technological cooperation between foreign and local firms. Further studies should then explore whether such cooperation does indeed translate into significant and positive spillovers in the country. Finally, focusing on the existing knowledge of MNEs alone, our results have pointed to some significant differences between WOS and IJV in their strategies towards R&D cooperation. Further studies have already demonstrated the importance of HQs and subsidiary roles in explaining innovation; future studies could combine contributions and explore in more depth the balance between firm-specific and country-specific factors, preferably by also including HQs in the analysis, with a view to better understanding the global dynamics of R&D cooperation within MNEs.

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Table 1. Variable Specifications

	Variable	Label
R&D Cooperation Strategy	R&D cooperation strategy Type 1, 2 and 3	*Cooperation type* (Used in the multinomial logistic model)
	Internal cooperation with MNE units, External cooperation with units outside the MNE	*Internal (External) cooperation* (Used in the simultaneous equation model)
Knowledge sourcing	External knowledge source, proxied by incoming spillovers	*Knowledge sourcing 1* (Scientific information from Non-profit organizations; Public research centres; Private research centres; Universities) *Knowledge sourcing 2* (Industrial Information from Business services, Suppliers, Customers, Competitors, New employees)
	Internal MNE Knowledge Source, proxied by Incoming spillovers	*Knowledge sourcing 3* (Information from other units of the MNE)
Subsidiary Technological Heterogeneity	Internal resources	*R&D Intensity*
	Competence-creating innovation activities	*CC Innovation* (Product diversification; New product introduction; Market power expansion; Total new market initiative effect)
	Competence-exploiting innovation activities	*CE Innovation* (Work environment improvement; Response to institutional change effect; Labour cost reduction; Other production cost reduction; Quality improvement; Flexible production)
Government Policy	Policy effects	*Policy 1* (Support for knowledge sourcing and exploration, Information services, Training support, Technology support) *Policy 2 (S*upport for exploitation and commercialization, through financing and public project opportunities) *Policy 3* (Tax benefits)
Control	Ratio of foreign ownership	*Foreign ownership*
	Technology type, based on NACE industry classification	*Tech 1* (Low technology, NACE 15, 16, 17, 18, 19, 20, 21, 22) *Tech 2* (Medium-low technology, NACE 26, 27, 28) *Tech 3* (Medium-high technology, NACE 25, 29, 34, 35) *Tech 4* (High technology, NACE 23, 24, 30, 31, 32, 33) *Tech 5*(Others, NACE 36)
	Years since establishment	*Age*
	Year dummy for 2005	*Year 2*

Table 2. Simultaneous Equation Model: Interaction between Cooperation Strategies

	Coefficient	t	Significance
***Equation 1:* Internal cooperation**			
(H1) External cooperation	0.647	1.990	**
Knowledge sourcing 3	0.207	2.610	***
R&D intensity	-0.077	-0.310	
CE Innovation	0.236	2.420	**
CC Innovation	0.226	2.430	**
Policy 1	0.029	0.260	
Policy 2	-0.088	-1.040	
Policy 3	-0.110	-1.390	
Age	0.006	0.650	
Foreign ownership	-0.001	-0.320	
Technology Type		Included	
Constant	0.400	1.010	
***Equation 2:* External cooperation**			
(H1) Internal cooperation	0.367	3.790	***
Knowledge sourcing 1	0.163	3.010	***
Knowledge sourcing 2	0.213	5.990	***
R&D intensity	-0.036	-0.340	
CE Innovation	-0.083	-1.810	*
CC Innovation	-0.128	-2.630	***
Policy1	0.142	3.550	***
Policy2	0.065	1.900	*
Policy3	0.088	2.580	***
Age	0.009	2.730	***
Foreign ownership	-0.001	-0.980	
Technology Type		Included	
Constant	0.219	1.340	
Equation 1:			
Number of observations			247
R-sq for Equation 1			0.512
F-stat for Equation 1			8.54
P-value			0.000
Equation 2:			
Number of observations			247
R-sq for Equation 2			0.686
F-stat for Equation 2			19.40
P-value			0.000

Note: * Significance at 10% level, ** Significance at 5% level, and *** Significance at 1% level

Table 3. Multinomial Logistic Models: Determinants of Subsidiaries' R&D Cooperation

	Model 1 Knowledge sourcing			Model 2 Subsidiary technological heterogeneity			Model 3 Government policy			Model 4 Full model			Model 5 Reduced Sample		
	Coef.	z	Sig.	Coef.	z	Sig.	Coef.	z	Sig.	Coef.	z	Sig.	Coef.	z	Sig.
Cooperation type 2, Internal cooperation															
(H2) Knowledge sourcing															
Knowledge Sourcing1	1.102	5.010	***							0.619	1.770	*	0.673	1.830	*
Knowledge Sourcing2	0.624	3.540	***							0.285	1.120		0.330	1.260	
Knowledge Sourcing3	0.807	3.850	***							0.522	1.950	*	0.518	1.820	*
(H3) Subsidiary heterogeneity															
R&D intensity				-0.200	-0.220					-0.068	-0.070		0.070	0.080	
CE Innovation				0.997	4.060	***				0.552	1.550		0.619	1.600	
CC Innovation				1.148	4.080	***				0.532	1.360		0.521	1.250	
(H4) Government policy															
Policy 1							0.597	3.690	***	0.114	0.570		0.076	0.360	
Policy 2							0.341	1.970	**	0.051	0.240		0.035	0.150	
Policy 3							0.477	2.930	***	0.082	0.420		0.137	0.660	
Control variables	0.045	2.220	**	0.023	0.990		0.028	1.640		0.019	0.750				
Age	0.002	0.210		0.001	0.080		-0.002	-0.190		0.001	0.080		0.041	1.530	
Foreign ownership	1.102	5.010	***							0.619	1.770	*	-0.002	-0.170	
Technology Type		Included			Included			Included			Included			Included	
Year2	-0.582	-1.250		-0.794	-1.750	*	-0.633	-1.620		-0.725	-1.280		-1.159	-1.850	*
Constant	-3.068	-2.530	**	-2.726	-2.180	**	-2.311	-2.100	**	-2.487	-1.830	*	-2.232	-1.620	
Cooperation type 3, External cooperation															
(H2) Knowledge sourcing															
Knowledge Sourcing1	0.882	3.460	***							1.142	2.500	**	1.998	2.630	***
Knowledge Sourcing2	0.559	2.720	***							0.633	2.120	**	0.558	1.230	
Knowledge Sourcing3	-0.534	-2.200	**							-0.683	-2.100	**	-1.038	-2.130	**
(H3) Subsidiary heterogeneity															
R&D intensity				-4.310	-0.490					-13.232	-0.930		-24.569	-0.870	
CE Innovation				0.455	1.900	*				-0.205	-0.510		-0.086	-0.160	
CC Innovation				0.396	1.540					-0.358	-0.820		0.028	0.040	
(H4) Government policy															
Policy 1							0.429	2.050	**	0.348	1.260		0.496	1.190	
Policy 2							0.443	2.260	**	0.416	1.650	*	1.223	2.820	***
Policy 3							0.552	2.800	***	0.761	2.760	***	1.372	2.960	***
Control variables															
Age	0.071	3.210	***	0.055	2.39	**	0.053	2.470	**	0.058	2.120	**	0.197	3.080	***
Foreign ownership	-0.017	-1.700	*	-0.025	-2.380	**	-0.016	-1.560		-0.016	-1.240		0.020	0.870	
Technology Type		Included			Included			Included			Included			Included	
Year2	0.654	1.250		0.130	0.260		-0.065	-0.130		0.530	0.760		-0.946	-0.820	
Constant	-2.131	-1.840	*	-1.557	-1.260		-1.463	-1.290		-2.333	-1.520		-6.850	-2.240	**
Number of observations		285			253			288			250			235	
LR chi2 (d/f)		111.70 (20)			76.52 (20)			61.80 (20)			116.92 (32)			129.90 (32)	

Prob > chi2	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.254	0.200	0.140	0.312	0.407

Note: Base outcome=Type 1 (No R&D cooperation)

* Significance at 10% level, ** Significance at 5% level, and *** Significance at 1% level

APPENDIX

Table A.1 Knowledge-sourcing

	Factor 1 (Knowledge sourcing 1, External scientific)	Factor 2 (Knowledge sourcing 2, External industrial)	Factor 3 (Knowledge sourcing 3, Internal)
Suppliers 1 (material)	0.86	0.224	0.198
Suppliers 2 (software)	0.814	0.254	0.23
Customers	0.776	0.324	0.206
Competitors	0.745	0.402	0.133
New employees	0.54	0.4	0.44
Nonprofit organisations	0.221	0.821	0.245
Public research centres	0.369	0.808	0.018
Private research centres	0.208	0.783	0.144
Universities	0.318	0.763	0.083
Business services	0.425	0.524	0.447
Intra-MNE units	0.245	0.102	0.891

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
KMO=0.924
Bartlett test of sphericity = 2957.083 (d.f. = 55, significance = 0.000)
Initial eigenvalue=6.323 (Factor 1), 1.156 (Factor 2), 0.718 (Factor 3)
Rotated eigenvalue=3.421 (Factor 1), 3.349 (Factor 2), 1.427 (Factor 3)
Criteria of factor extraction: Kaiser criterion (Rotated value), interpretability criterion, total variance criterion
Cumulative total variances = 82.086%

Table A.2 Subsidiary's heterogeneity: Type of technological activity

	Factor 1 (Competence-exploiting activities)	Factor 2 (Competence-creating activities)
Work environment improvement	0.850	0.361
Labour cost reduction	0.818	0.425
Production cost reduction	0.797	0.468
Compliance with institutional change	0.785	0.413
Quality improvement	0.741	0.559
Flexible production	0.738	0.460
New market initiative	0.651	0.627
Product diversification	0.420	0.847
New product introduction	0.380	0.845
Market power expansion	0.554	0.751

Extraction Method: Principal Component Analysis. / Rotation Method: Varimax with Kaiser Normalization. / KMO=0.946
Bartlett test of sphericity = 4927.048 (d.f. = 45, significance = 0.000)
Initial eigenvalue=7.854 (Factor 1), 0.546 (Factor 2)
Rotated eigenvalue=4.788 (Factor 1), 3.612 (Factor 2)
Criteria of factor extraction: Kaiser criterion (Rotated value), interpretability criterion, total variance criterion
Cumulative total variances = 83.998%

Table A.3 Types of innovation policy

	Factor 1 (Policy 1, exploration & implementation support)	Factor 2 (Policy 2, exploitation & commercialization support)	Factor 3 (Policy 3, tax support)
Information service	0.858	0.189	0.226
Training	0.855	0.192	0.24
Technology support	0.775	0.381	0.061
Financing	0.178	0.821	0.289
Public project opportunity	0.334	0.795	0.125
Tax	0.262	0.287	0.909

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
KMO=0.852
Bartlett test of sphericity = 1102.181 (d.f. = 15, significance = 0.000)
Initial eigenvalue=3.541 (Factor 1), 0.827 (Factor 2), 0.557 (Factor 3)
Rotated eigenvalue=2.281 (Factor 1), 1.606 (Factor 2), 1.038 (Factor 3)
Criteria of factor extraction: Kaiser criterion (Rotated value), interpretability criterion
Cumulative total variances = 74.519%

Table A.4 Descriptive statistics

Variable	Freq.	Mean	Std. Dev.	Min	Max
Cooperation type (Type 1,2, 3) Of which:	293	0.379	0.670	0.000	2.000
No R&D cooperation (Type 1)	213			..	..
Internal R&D cooperation (Type 2)	49	..	..	..	..
External R&D cooperation (Type 3)	31	..	..	..	..
R&D intensity	265	0.033	0.276	0.000	4.000
Age	291	16.478	10.100	1.000	57
Foreign ownership	293	80.962	21.215	50.000	100.000
	Total	Type 1 No R&D Coop.	Type 2 Internal R&D Coop.	Type 3 External R&D Coop.	
Of which Joint Ventures	156	104	29	23	
Wholly-owned	137	109	20	8	

Table A.5 Correlation matrix

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Cooperation type (used in Modes 2,3, 4 & 5)	1.000													
2	Internal cooperation (used in Equation 1 in Model 1)	0.450	1.000												
3	External cooperation (used in Equation 2 in Model 1)	0.705	0.747	1.000											
4	Knowledge sourcing 1	0.330	0.404	0.400	1.000										
5	Knowledge sourcing 2	0.220	0.058	0.286	-0.071	1.000									
6	Knowledge sourcing 3	0.012	0.252	0.150	0.135	-0.065	1.000								
7	R&D intensity	-0.029	-0.003	-0.029	-0.082	0.002	0.099	1.000							
8	CE Innovation	0.222	0.280	0.285	0.425	0.207	0.411	0.046	1.000						
9	CC Innovation	0.223	0.302	0.289	0.557	0.187	0.280	0.028	0.093	1.000					
10	Policy1	0.220	0.297	0.391	0.397	0.070	0.146	0.078	0.178	0.341	1.000				
11	Policy2	0.169	0.024	0.143	0.061	0.317	0.063	0.018	0.176	0.038	-0.106	1.000			
12	Policy3	0.234	0.088	0.156	0.222	0.038	0.206	-0.072	0.230	0.291	0.036	-0.122	1.000		
13	Age	0.147	0.023	0.114	-0.082	-0.036	0.091	0.035	-0.015	-0.114	-0.075	0.061	0.037	1.000	
14	Foreign ownership	-0.215	-0.122	-0.201	-0.174	-0.123	0.046	0.075	-0.119	-0.146	-0.129	-0.168	-0.091	-0.073	1.000