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Dual Boundary Spanning—Toward a Typology of Outside-In Open Innovation in the Canadian Context

Abstract

The extant literature runs short in understanding openness of innovation regarding different pathways along which internal and external knowledge resources can be combined. This study proposes a unique typology for outside-in innovations based on two distinct ways of boundary spanning: whether an innovation idea is created internally or externally and whether an innovation process relies on external knowledge resources. This yields four possible types of innovation, which uniquely represent the nuanced variation of outside-in innovations. Using historical data from Canada for 1945–1980, this study unveils different implications of these innovation types for different levels of innovation novelty.

Keywords

Open innovation; resource-based view; outside-in innovation types; external knowledge

Introduction

Driven by increased market competition and rapid technological change, firms have increasingly pursued an open innovation model that involves external actors and sources to enhance innovative performance and competitiveness (Chesbrough, 2003). In general, an open innovation strategy provides firms with additional opportunities for learning and earning compared to a closed approach, but there are many ways of being open (Enkel et al., 2009; Dahlander & Gann; 2010; Huizingh, 2011).

The distinctive modes of open innovation are predominantly based on the notion of firm boundaries (Dahlander & Gann, 2010; Laursen & Salter, 2004; Leiponen & Helefat, 2010). The outside-in mode, in which a firm enriches its own knowledge base by searching, selecting, and integrating external knowledge and eventually captures value by commercializing innovations generated by the combination of external knowledge with internal resources, is a distinct mode of open innovation (Enkel et al., 2009). The outside-in process has received a great deal of attention from researchers (West & Bogers, 2014), but our understanding of its workings is still surprisingly limited; an overly simple and streamlined process involving three steps—obtaining knowledge (from external sources), integrating it (with internal knowledge base), and commercializing it (by the focal firm)—has remained the prevailing model (West & Bogers, 2014; Love et al., 2011). Researchers have yet to develop a nuanced understanding of how multiple combinations of internal and external knowledge eventually leads to innovations.

In this study, I begin to address this gap by proposing a unique typology for outside-in innovation based on the two distinct ways of boundary spanning: (1) An innovation idea is created and developed internally or externally, and (2) the innovation process relies on external

knowledge resources or not. This categorization yields a matrix of four possible types of innovation that represent the nuanced variations in outside-in innovation. To date, the literature on outside-in innovation has neither theoretically elaborated on nor empirically tested the effects of these two ways of boundary spanning in relation to innovation outcome measures. Thus, this study contributes to the literature by shedding light on the dynamics of interactions between internal knowledge and externally sourced knowledge and the influence of those dynamics on firms' innovation potential (West & Bogers, 2014) and by providing insights on a critical question—How can a unique typology of outside-in innovation based on different pathways for internal and external knowledge combination help us to better understand the implications of outside-in innovation for firms' innovation outcomes? To this end, the study uses historical data on technological innovations by Canadian companies to illuminate the relationships between different types of outside-in innovation and innovations at different levels of novelty and to demonstrate one possible way of operationalizing the typology. Suggestions on how to apply the typology to other empirical research settings are offered to guide future research.

This article is organized as follows: First, I briefly review the literature on the outside-in innovation and illustrate the research gap. Second, a new typology of outside-in innovations is proposed. Next, I demonstrate the validity and usefulness of the typology, using data from the Canadian context. Hypotheses regarding the likelihood of generating innovations at different levels of novelty are developed and tested. Finally, after the results are presented, I conclude with an in-depth discussion of the application of the typology to future empirical research.

Theory and Conceptualization

The conceptualization puzzle of openness in innovation

The notion of open innovation is based on an observation that firms are less and less likely to make successful innovations alone because critical resources, such as technology, knowledge, talented employees, and market opportunities, are often available only outside the firms' boundaries (Chesbrough, 2003). The extent to which a firm employs open innovation, meaning how external knowledge is combined with internal resources and where value is created and captured, is related to the firm's boundary (Dahlander & Gann, 2010). Open innovation can be deployed using inside-out or outside-in processes, or a combination of both (Enkel et al., 2009). The inside-out process is exemplified in firms' external commercialization channels, such as licensing out, selling IP, and technology transfer (e.g., Fosfuri, 2006; Ziedonis 2007). The outside-in process, by contrast, is concerned with whether and to what extent a firm makes use of external knowledge elements (e.g., Laursen & Salter, 2006; Leiponen & Helfat, 2010) or cites other organizations' patents (Rosenkopf & Nerkar, 2001). Other researchers implicitly confirm that the outside-in approach is linked to collaboration with various types of partners (Gulati & Singh, 1998; Belderbos et al., 2004; van Beers et al., 2008).

Although the general distinction between inside-out and outside in processes is useful and insightful, it remains vague to some extent because it is not clear whether the boundary criterion, the difference between "in" and "out," is determined by where an innovation is commercialized or where the innovative idea is created. Scholars clarify this theoretical distinction by distinguishing two dimensions of boundary spanning: first, whether an innovation idea is created inside or outside of the focal firm (Audretsch, 1998), and second, whether an innovation is

commercialized by the focal firm or by other firms (Bogers & West, 2010; Figure 1). According to the typology suggested by Bogers and West (2010), if an innovative idea is created inside the firm and commercialized outside, the innovation process is an inside-out process. If an innovative idea is created outside and commercialized outside, then the firm is participating in co-creation and the value capture is not always under the focal firm's control. When an innovative idea is created outside and commercialized inside, this is a typical outside-in process. Prior work largely follows this simple and streamlined definition of outside-in innovation & Bogers, 2014), assuming that in outside-in processes, ideas are created somewhere else and the focal firm obtains them through various means (e.g., licensing, acquiring, joint R&D), recombines and integrates them with internal resources and capabilities, and finally launches innovative products or services based on the internalized ideas into the market (e.g., Grimpe & Kaiser, 2010; Du et al., 2014). When an innovation idea is both created and commercialized inside the firm, the innovation process is generally regarded as closed. However, since open innovation is defined as a firm's purposive use of knowledge inflows and outflows that may take place at any stage of a porous innovation funnel (Chesbrough et al., 2006), even an idea that is created internally and commercialized by the focal firm could still be developed through outside-in innovation, as long as an internally created innovative idea is combined at some point along the innovation funnel with some external knowledge, which the focal firm makes an intentional effort to search for, select, and integrate into its knowledge base (Love et al., 2011).

Insert Figure 1 here (adapted from Bogers & West 2010)

This observation complicates the widely accepted generic distinction between inside-out

and outside-in innovation processes and demonstrates that the existing typology of innovation in the literature does not sufficiently address all of the nuances of outside-in innovation. This study, thus, proposes a new typology for outside-in innovation, illustrating the multiple paths that connect internally and externally created ideas with internal or external knowledge resources in an outside-in innovation process based on a dual boundary spanning logic.

A typology of outside-in innovation and its theoretical foundations

A closer look at the locus of idea creation (Rosenkopf & Nerkar, 2001) and the multiple pathways through which internal and external knowledge resources may be combined suggests a basis for a new typology. First, when an innovative idea is created internally, a firm may either continue developing it alone, either relying solely on its own internal knowledge, or relying on both internal knowledge (which is inevitable) and knowledge from external partners who have complementary knowledge for the further development of the innovation. Here we see one possibility for boundary spanning and two potential paths: the first—relying solely on internal knowledge—is a totally closed approach to innovation, and the second—accessing partners' resources—entails collaborative innovation drawing on complementary external knowledge.

Second, an innovative idea may be created and developed outside a focal firm by a primary external partner through, for example, outsourced R&D or knowledge spillover. Here we see another possibility for boundary spanning and two potential paths for the focal firm: the firm can integrate an innovative idea created by a primary external partner either using its internal knowledge base exclusively or using both its internal knowledge base and the knowledge resources of external partners *other than* the primary one who created the innovative idea.

These four pathways are illustrated in Figure 2. They can be clarified by a configuration based on the two unique ways of firm-boundary spanning: whether a firm relies on external knowledge elements other than those of the primary external innovation source and whether an innovative idea is created internally or externally. Given the dual boundary-spanning possibilities, four distinct types of outside-in innovation can be distinguished (see Figure 3). First, *totally closed innovation* (type I) denotes those that are internally created, having no reliance on external technologies at all; this is by definition closed innovation. Type II, *complementary learning*, describes cases where the idea is developed internally and complementary knowledge is drawn from various external partners in the process of developing it. Next, Type III, *total outside-in*, represents those innovation processes in which the original idea is developed outside the focal firm and other external technologies are integrated in its development. Finally, Type IV, *focused sourcing*, encompasses innovations in which the idea is created by a primary external partner but only internal knowledge is used to further develop the innovation. To simplify terminology, in the rest of this paper, I refer to totally closed innovation, complementary learning, total outside-in, and focused sourcing as types I, II, III, and IV innovations, respectively.

Insert Figure 2 here

Insert Figure 3 here

This proposed typology of outside-in innovation finds its theoretical foundation in the central proposition of Schumpeterian theory, which posits that there are two basic ways in which innovative activities are structured and organized: Schumpeterian Mark I and Mark II

(Schumpeter, 1934; Breschi et al., 2000). The Schumpeter Mark I is characterized by "creative destruction" (widening), and Mark II is associated with "creative accumulation" (deepening). Mark I suggests the creation of new knowledge paths and sometimes the creation of new ventures; Mark II instead stresses the firm's accumulated internal stock of knowledge in specific technological areas and its competencies in R&D, production, and distribution. Mark I (widening) often requires firms to access external knowledge to create disruptive paths toward innovation, while Mark II (deepening) requires firms to strengthen their internal knowledge bases and innovation capabilities (Malerba & Orsenigo, 1994). In the proposed outside-in typology, Schumpeterian Mark I and Mark II are reflected by the dimension indicating whether a focal firm relies on external knowledge.

The typology is also theoretically rooted in the literature on the resource-based view (RBV) (Barney, 1991; Teece, et al., 1997) and the relational view (Dyer & Singh, 1998; Lavie, 2006) of firms. From a RBV the typology is built on the two generic origins of firm resources: internally developed resources are derived from a firm's prior path (Teece, et al., 1997; Teece, 2007), and external resources are acquired under pressure in idiosyncratic situations (Ahuja & Katila, 2004). Sometimes, a firm's internal resources and capabilities are not sufficient to allow further development of an innovation. In this case, the firm must seek external knowledge that is complementary to both the original concept and its own limited knowledge base (Kogut & Zander, 1992; Doloreux, 2015). This need leads to the development of various collaborative relationships; it is in this context that the relational view becomes relevant. The relational view suggests that a firm's competitive advantage arises not only from its internal resources but also from "appropriated relational rent" resulting from the recombination, exchange, and co-

development of shared resources with partners; a firm may also receive unintended benefits from partners' resources, both those that are shared and those that are not, through an "inbound spillover" effect (Lavie, 2006).

A simple typology as such, built on Schumpeterian innovation theory, the RBV and the relational view can be powerful to provide new insights. The two-by-two typology design is a typical configurational approach to conceptualize complicated phenomena. It is often used by scholars in management science because it is an unambiguous means of presenting a description of reality (Meyer et al., 1993). It allows people to prioritize and make sense of the world by sorting things into discrete and relatively homogenous categories, because organizational structures and management systems are well understood in terms of overall patterns (Meyer et al., 1993). However, a typology is no hypothesis. Rather, it offers guidance in the construction of hypotheses, which need to be formulated, argued, and tested within a given context (Weber, 1963). In the next section, I will demonstrate the usefulness of this typology using data from the Canadian technological innovation landscape and develop hypotheses regarding the relationships between outside-in innovation types and innovation outcomes at different levels of novelty in this specific innovation context.

Showcasing Canadian Technological Innovation

The proposed typology of outside-in innovation seems simple, powerful, and straightforward; however, it must also be useful for analyzing industrial innovations in reality and measured by a consistent approach. I hereby focus on Canadian innovations during 1945–1980, a period long enough to allow examination of the evolution of industrial innovation through the lens of the typology.

Canadian technological innovations, 1945–1980

The analysis draws on a well-preserved longitudinal data archive about Canadian technological innovations, covering 1,635 new or improved industrial products or processes introduced in Canada from 1945 to 1980, held at the library of the University of British Columbia. The data concern 550 innovating firms and about 2,500 related companies (customers and suppliers), covering 79 industries. The Canadian data have a high level of nationwide representativeness in three respects: industry coverage, firm size, and geographic distribution. From the data, detailed information on the year of first introduction, firm size, industries in which the firms are active, user firms, competitors, and the locus of innovation development for each innovation is available. A detailed description about the Canadian data can be found in DeBresson's (1996) work.

To showcase the different types of outside-in innovations in this study, a sample is selected from the Canadian data, following a number of criteria to ensure sample reliability. First, the cases in which respondents failed to indicate the novelty of the innovation were excluded. Second, the cases in which the answers to the questions regarding the novelty of an innovation were illogical are also removed. These cases were mostly likely to occur when respondents were asked to recall innovations introduced in the early years of the data set. Applying these selection criteria yielded a sample of 1,209 cases, each of which represents an observation of a specific innovation introduced by a specific Canadian firm in a particular year in the period of study.

Outside-in innovation types vis-à-vis novelty levels of innovation outcome

The typology for outside-in innovation is defined by two distinct dimensions of firm boundary spanning: whether an innovation idea is created and developed internally or externally and whether an innovation process relies on external knowledge resources or not. The first dimension

corresponds to question 8a in the Canadian survey, which asks where an innovation was originally developed. If the respondent indicated that the innovation was developed in "the establishment within your company that first produced the product" or "another establishment in the same company," the innovation is interpreted as having been internally developed by the focal firm. If the firm indicated that an innovation was developed by "other establishments or companies," it is interpreted as having been developed by an external primary partner. The second dimension is indicated by question 8b, which asks for a qualitative description of what resources were supplied to the focal firm by partners to support the development of the innovation. An innovation is categorized as using external technologies only if the firm's response indicated that its suppliers provided knowledge elements, such as technologies, patents, engineering design, R&D, formulation, or other knowledge resources. An innovation was not regarded as relying on external knowledge if the firm indicated receiving only concrete resources, such as money, raw material, distribution, machinery parts, or equipment. With all the innovations coded in this way using two dummy variables, it is possible to code them into four different types using four nominal variables. To illustrate these four types of innovation, some real examples from the data are provided in Table 1, which also shows the overall distribution of the innovation types in the entire sample.

Insert Table 1 here

Based on historical anecdotes, Trott and Hartmann (2009) show that major innovations in human history have followed a mix of open and closed modes long before the paradigm shift suggested by Chesbrough (2003). Given this trend, I expected that the overall patterns of outside-

in innovation types in the Canadian data might differ during different time periods. Therefore, some preliminary data analyses were conducted to explore whether there had been important pattern changes across time periods. The distribution of different innovation types throughout the observation period was examined to identify evident historical patterns of change among Canadian innovations. Figure 4 presents the yearly distribution of innovation types in absolute numbers. The figure shows two relatively clear cuts in innovation productivity, creating three defined periods within the sample, 1945–1959, 1960–1976, and 1977–1980. In the period 1945–1959, the number of innovations was very small; 1960–1976 accounted for the greatest portion of the innovations and the number of innovations significantly decreased again in the period 1977–1980. Although we do not know the exact reasons for these differences (i.e., regulatory change; see Mowery, 2009), they clearly suggest the existence of three structurally different periods with regard to the magnitude of innovations in Canada. However, this structural difference does not hold with regard to the types of innovations. Aside from the dominant presence of type I (totally closed innovations) across the three periods, the distribution of types II, III, and IV seems somewhat random. This finding hints that the diffusion of innovation types might be associated with nuanced differences across innovation novelty levels.

Indeed, innovations in the Canadian data were also categorized according to their novelty with respect to market introduction. This analysis relied on questions regarding the newness of an innovation at the time it was marketed. Respondents were asked whether the company was the first to market an innovative product in Canada. If so, a further question asked whether the same or a similar product had been marketed outside of Canada before. This set of questions allows the innovations in the data to be categorized into three levels of novelty: *pioneering innovations*,

new-to-Canada innovations, and *new-to-firm-only innovations*. Pioneering innovations are new to the world at the time of their commercialization by the focal firm (Cozzarin, 2006; Li & Vanhaverbeke, 2009a; Czarnitzki et al., 2011). Pioneering innovations possibly entail the highest level of novelty in both the technology and product-market domains (Amara & Landry, 2005; Larsen & Salter, 2006), having the potential to create relatively long-lasting and significant competitive advantages for the focal firm over its competitors. Meanwhile they entail a high level of risk (Zahra et al., 1995; Hill & Rothaermel, 2003). Prior studies have explored the likelihood that a firm will generate pioneering innovations in relation to foreign competition, absorptive capacity, and the difference between the focal firm and its suppliers across countries and industries (Li & Vanhaverbeke, 2009a; 2009b). New-to-Canada innovations represent early adoption of advanced technologies that have been developed elsewhere—in most cases, in the United States—and the introduction of new products into the Canadian market. Finally, new-to-firm-only innovations were new to the innovating firm, but similar products had been introduced to Canada before.

Insert Figure 4 here

Hypotheses

Pioneering, new-to-Canada, and new-to-firm-only innovations, by definition, differ from each other in terms of their demand for external knowledge and the firm's need to control collaborative risk. Thus, the diffusion of outside-in innovation types can perhaps be better understood in relation to these levels of novelty and their relationships are hypothesized in this section.

From a classical transaction cost economics (TCE) viewpoint, the newer an innovation, the tighter the control needed to prevent information leakage (van de Vrande et al., 2009). The RBV seems to reinforce this view by emphasizing the possession and appropriation of resources that are valuable, rare, inimitable, and non/substitutable (VRIN resources) before competitors. Taken together, these principles suggest that pioneering innovations require tight control of the innovative idea and any attached intellectual properties. When a new idea is created by the firm itself, the firm can either go it alone to develop the idea, if it has the capabilities, or collaborate with external partners who have complementary knowledge only if it is necessary. In the latter case, external learning is involved, but as the focal firm actually generated the innovative idea, it usually possesses a decent level of absorptive capacity required to understand and integrate most of the complementary knowledge. Therefore, the learning challenge is not unsurmountable. However, if the innovative idea is created by an external party and acquired by the firm, the cost of initial learning and coordination to fully understand the application and its economic value may be quite high. In addition, as the idea was created externally, it may be difficult to guard against the development of alternative avenues of value creation by the original inventor, due to behavior uncertainty (Heide, 1994).

These potential obstacles may cause the focal firm to lose its momentum of introducing a pioneering innovation. Thus, I expect that innovative ideas created by the focal firm itself, regardless of whether the firm draws on external complementary knowledge or not, are more likely to yield successful pioneering innovations than externally developed innovative ideas. With regard to the outside-in typology, this suggests that type I and type II (*totally closed innovation* and *complementary learning*) are probably more suitable for pioneering innovations

compared to type III and type IV (*total outside-in* and *focused sourcing*).

Moreover, between type I and type II innovations, the latter, *complementary learning*, might entail higher relational risks, even though learning from partners might not be very challenging. Instead of hoping to capture relational rents, the opposite might be true for complementary learning from a relational view, meaning that a firm's external partners may race against the focal firm to seek higher relational rents, or harvest relational rents more quickly because the incentive to profit from pioneering innovation is strong. After all, the opportunities provided by a relationship are mutual (Lavie, 2006). Collaboration with a number of external knowledge partners also creates a higher risk of knowledge spillover, which jeopardizes the chance of being the first to introduce a pioneering innovation. Thus, type II innovation in the context of a pioneering innovation nevitably requires a great deal of relational and contractual governance to control external agents (Felin & Zenger, 2013), and the design and implementation of safeguard mechanisms will incur extra costs (Leiponen & Byma, 2009). The real option theory also suggests that firms developing pioneering technologies need to start small in investing in external partnerships (van de Vrande et al., 2009; 2011). All in all, I anticipate that the *totally closed* type of innovation might be best suited to pioneering innovations compared with the other three open types of outside-in innovations. This reasoning leads to the first hypothesis:

H1: Ceteris paribus, type I innovation (totally closed) is most likely to be associated with pioneering innovations, compared to types II, III, and IV.

In most cases, new-to-Canada innovations were introduced by first movers that adapted technologies and product designs developed in the United States to the Canadian market.

Canadian first movers needed to make sure that foreign technologies could be adopted by the local Canadian context, given key local market characteristics, such as customer needs, the demands of technical performance in probably different natural environments, logistical systems, and finance structures. Therefore, access to local knowledge in both the technology and market domains could be crucial for the success of these innovations (Jaffe, 1986; Rosenkopf & Nerkar, 2001). Prior research also suggests that collaborations with local knowledge partners who can supply complementary local knowledge in a wide range of domains, such as engineering, product design and development, and marketing research play an essential role in integrating externally acquired foreign technologies (Wang & Li-Ying, 2015). These findings suggest that type III (total outside-in) should be the innovation type most popularly associated with new-to-Canada innovations. These arguments yield the second hypothesis:

H2: Ceteris paribus, type III innovation (total outside-in) is most likely to be associated with new-to-Canada innovations, compared to types I, II, and IV.

New-to-firm-only innovations were not new in the Canadian market, but they were still new to the firm. These were indeed very rare cases in the Canadian data. Presumably, they are the result of highly specialized product/process differentiations that aimed at niche market segments. These firms pursued "niche" strategies in the sense that they focused on serving the needs of a particular group of customers with special needs that demanded special technical know-how (Cooper et al., 1986). A niche strategy can be used effectively by both large and small firms (Parrish et al., 2006). Firms that succeed at a niche strategy proactively explore unmet customer needs and highly differentiate their offerings from mainstream or competitors' products (Salter & Mohr, 2006). Innovations in niche market have reasons to survive and potentially

evolve to a future paradigm change if certain internal and external conditions are met (Schot & Geel, 2008). Alternatively, these new-to-firm-only innovations could be process innovations that were particularly beneficial to the specialized manufacturing process of a focal firm.

As the application scope of these innovations to the niche market or internal process is relatively limited at the beginning, and their market size may be unproven, they are not so attractive to external partners to consider making substantial knowledge contributions (Cooper et al., 1986; Salter & Mohr, 2006). In these cases, the focal firm is likely to draw on a proven concept from an external source and deepen its knowledge base by best utilizing its own in-house know-how, which is probably the most valuable knowledge complementary to the original innovative idea. This line of thinking suggests that type IV (focused sourcing) is likely to be most popularly associated with new-to-firm-only innovations. The third hypothesis, thus, is developed as following:

H3: Ceteris paribus, type IV (focused sourcing) is most likely to be associated with new-to-firm-only innovations, compared to types I, II, and III).

Measures and estimation models

Even though it is a relatively old data set, the Canadian data has been used to test hypotheses related to innovation activities and outcomes in recent studies (Li & Vanhaverbeke, 2009a; 2009b). In this study, I use measures similar to those employed by these prior studies to ensure comparable results.

Dependent variables. Three binary dependent variables are used to indicate whether an innovation is pioneering, new-to-Canada, or new-to-firm-only. “Pioneering innovations” are those introduced to the world first in Canada and had no similar products introduced outside of

Canada before that. “New-to-Canada innovations” are those that are new to the Canadian market, although similar products had been introduced elsewhere in the world. “New-to-firm-only innovations” are those that were new to the firm but not to the Canadian or world markets.

Independent variables. The four nominal variables representing the four outside-in innovation types are the independent variables. Having four, instead of three, dummy variables makes it easy to set the reference group (omitted category) and enables multiple ways of comparison.

Control variables. First**,** firms of different *sizes* innovate differently (Almeida & Kogut, 1997; Powell & Brantley, 1992). Thus, I control for firm size, measured by the number of employees at the time the innovation was introduced to the market. Second, competition matters for innovation (Tang, 2006); firms make different strategic moves in the face of different competitive situations. Thus, it is also necessary to control for the level of *competition*, measured as the number of competitors. This information is captured in the survey by a question asking respondents to list the names of both domestic and foreign competitors. This method captures the information on all the *de facto* competitors or perceived competitors, regardless how they compete (Li & Vanhaverbeke, 2009b). Next, the primary *industry* to which the innovating firms belong is controlled for using nine dummy variables. Finally, firms with successful experiences in a previous period gain positive feedback and learning from the past, making them more likely to innovate again (Walsh & Ungson, 1991), but successful experience may also trap innovating firms, leading them to rely on exploitative innovations rather than exploring completely new opportunities (Ahuja & Lampert, 2001; Audia & Goncalo, 2007). Thus, I also control for *past experience,* measured by the ratio of the number of pioneering innovations introduced by a firm to its total number of innovations during the ten years preceding the introduction of an

innovation.

Estimation model. Given the binary nature of the dependent variables, binary logistic regression models are the logical choice to probe the relationships between outside-in innovation types and innovation novelty levels. Binary logistic regression is used to predict a dichotomous variable from a set of predictor variables, which are a mix of continuous and categorical variables, regardless of how these predictor variables are distributed. The predicted dependent variable is a function of the probability that a particular subject will be in one of the categories. In this case, the binary logistic regression predicts the probability that an innovation will be a pioneering, new-to-Canada, or new-to-firm innovation, given the value of a set of predictor variables. The advantage of using binary logistic regression is that it becomes easy to compare different categories of a construct (innovation types) by checking the significance level and relative odds ratios for each category. As time may have an effect on these predicted relationships due to changes in national and international economies, sociopolitical environments, and other sociotechnical factors, three binary regression models corresponding to the three identified historical periods (1945–1959, 1960–1976, and 1977–1980) are calculated for each dependent variable to show any time-specific effects that are not captured by the independent variables.

Empirical results

The descriptive statistics and correlations between the variables are presented in Table 2. Innovating firms in the sample have on average more than two competitors. The average size of innovation firms is 3.080, corresponding to a firm size of 200–499 employees. There is no high correlation between any pairs of dependent variable and independent variable.

Insert Table 2 here

Tables 3, 4, and 5 present the results of binary logistic regression to test each of the hypotheses, with pioneering, new-to-Canada, and new-to-firm-only innovations, respectively, as the dependent variable. All models meet the Hosmer-Lemeshow test, indicating that the data fit the models well. In table 3, for the period 1945–1959, when types II, III, and IV are compared with the reference group, type I, with regard to pioneering innovation, the coefficients of types II and III are negative and significant (β=–0.731, $p<0.10$, odds ratio=0.481; β=–1.859, $p<0.01$, odds ratio=0.156, respectively). This result indicates that the odds that an innovation is pioneering for type II (complementary learning) and type III (total outside-in), were 0.481 times and 0.156 times, respectively, those for type I (totally closed innovation). During 1960–1976, only the coefficient of type IV is negative and significant (β=–0.461, $p<0.05$, odds ratio=0.631). This result means that the odds that an innovation is pioneering for type IV (focused sourcing) were 0.631 times those for type I during that period. But types III and IV innovations were not statistically better or worse off than type I innovations with regard to the likelihood of being pioneering. Finally, during 1977–1980, only the coefficient of type III is negative and significant (β=–1.628, $p<0.10$, odds ratio=0.196). This means that the odds that an innovation is pioneering for type III (total outside-in) were 0.196 times those for type I during that period. These findings suggest that (1) during 1945–1959, type II (complementary learning) and III (total outside-in) innovations were less likely to be pioneering than type III and IV innovations; (2) during 1960–1976, type IV (focused sourcing) innovation was least likely to be associated with pioneering innovations; and (3) during 1977–1980, type III (total outside-in) innovation was least likely to yield pioneering innovation. In general, type I (totally closed) innovation seemed more popular

for pioneering innovations than other open types, partially supporting H1.

Insert Table 3 here

In table 4, during 1945–1959, compared with the reference group (type I), only the coefficient of type III is positive and significant (β=1.326, p<0.05, odds ratio=3.766) with regard to new-to-Canada innovation. This result indicates that the odds that a type III (total outside-in) innovation was new to Canada were 3.766 times higher than those for type I. During 1960–1976 no other types were better or worse off than the reference group (type I), as none of the coefficients for types II, III, and IV are significant. Finally, during 1977–1980, only the coefficient of type III is positive and significant (β=1.961, p<0.05, odds ratio=7.110). This result means that the odds that a type III innovation was new to Canada in this period were 7.110 times higher than those for type I. These findings suggest that (1) during 1945–1959 and 1977–1980, type III (total outside-in) innovation was the most likely to be associated with new-to-Canada innovations compared to other innovation types, supporting H2; and (2) during 1960–1976, all four innovation types were evenly distributed among new-to-Canada innovations, a conclusion that does not support H2.

Insert Table 4 here

In table 5, during 1945–1959 and 1977–1980, no other types were better or worse off than the reference group (type I) with regard to new-to- firm-only innovation, as none of the coefficients for types II, III, and IV are significant. However, during 1960–1976, compared with the reference group, the coefficient of type IV is positive and significant (β=0.987, p<0.01, odds

ratio=2.683). This result means that the odds that a type IV (focused sourcing) innovation is new to the firm only for that period were 2.683 times higher than those for type I. These findings suggest that (1) during 1945–1959 and 1977–1980, all four innovation types were evenly distributed among new-to-firm-only innovations, not supporting H3; and (2) during 1960–1976, type IV (focused sourcing) innovation was most likely to be associated with new-to-firm-only innovations, supporting H3.

Insert Table 5 here

These results must be interpreted with caution. First, they confirm the hypotheses to some extent, but when different time periods are specified, the hypotheses are not fully confirmed. Second, although a particular type of outside-in innovation is more likely to be associated with a particular level of innovation novelty than other innovation types, this should not be interpreted to mean that other types cannot produce that innovation outcome. In fact, based on the contingency theory, which suggests that firms' performance is a function of fit between context and conduct (Drazin & Van de Ven, 1985), the analytical power of the typology depends on external and internal factors specific to particular firms, such as market competition, technology, business strategy, and organizational context (Foss et al., 2011; Lazzarotti et al., 2011; 2015). The test of hypotheses in this study is merely intended as an example to showcase the power of the typology to explain firms' innovation outcomes when other contingencies are controlled for.

Discussion

Summary

This study contributes to the literature on strategic management of innovation by suggesting a

new typology based on the logic of dual boundary spanning. Prior studies on open innovation typically define openness in terms of breadth (the number of external knowledge sources) and depth (the importance of external collaborations), but they could tell little about where the innovation idea is developed and what external knowledge is sourced from which external knowledge partners (e.g., Laursen & Slater, 2006; Drechsler & Natter, 2012; Lazzarotti et al., 2015). This yields many possibilities for future research following the typology to enrich the literature in this regard. The outside-in innovation types can be used as dependent, independent, or contingency variables, depending on the research design. Future research is encouraged to use more recent data in a longitudinal manner to deepen understanding of the openness of innovation.

Contributions to scholarship

Used as dependent variable. It will be highly interesting to further investigate why and in which conditions firms choose a certain type of openness for a specific type of innovation. In this case, the types of innovation defined in the typology can be used as dependent variables, which can be determined by a number of internal and external factors (Drechsler & Natter, 2012). Some plausible relationships could be argued and tested. For instance, from a relational view, positive prior collaborative experience with a knowledge partner could make a firm more confident to take on riskier types of innovation (Gulati, 1999; Lambe & Spekman, 1997; Hagedoorn, 2003). By the same token, firms with strong R&D capabilities might be equally capable of engaging in complementary learning and focused sourcing (Sun & Du, 2000), while others that have a high level of dynamic managerial capabilities might be able to undertake riskier innovation projects of the total outside-in type (Helfat & Martin, 2015). The choice of an innovation type could also be a joint function of external competition (Li & Vanhaverbeke, 2009b), appropriability regimes

(Anand & Khanna, 1997), the availability of knowledge clusters (Tallman et al., 2004), and proximity to local knowledge partners (Li-Ying et al., 2014).

Used as independent variables. The choice of an innovation type may have implications for innovation outcomes. Thus, the types of outside-in innovation can be used as independent variables to explore these relationships. For instance, as different innovation types entail different degrees of external learning and coordination, they may to some extent determine the speed-to-market and development costs (Gulati & Singh, 1998; Bayus, 1997), which in turn have implications for the market value of an innovation (Hall et al., 2005). Regarding firms' internal factors, a particular type of outside-in innovation may impose challenges on a firm to further develop new organizational capabilities accordingly (Feldman, 2000). Organizational context may mediate the effect of innovation types on innovation outcomes (Lazzarotti et al., 2015; Foss et al., 2011). A particular type of outside-in innovation may also be equipped with different contractual governance mechanisms (Nooteboom, 2004). Here the dynamism of the relationships among types of openness, selection of governance mechanisms, and development of dynamic capabilities offers a promising research direction (Teece, 2014).

Used as contingency variables. Innovation is commonly considered a value creation and value capture process through which inputs and outputs repeatedly interact (Love et al., 2007; West & Bogers 2014). The typology can also be combined with innovation phases (Lazzarotti et al., 2011). In this respect, the outside-in innovation types can be used as contingency variables to set conditions under which knowledge resources are transformed into innovation performance. For instance, the breadth and depth of external knowledge searching (Laursen & Salter, 2006) might not sufficiently explain the innovation performance of a firm: instead, performance may

depend on which innovation type a firm deploys at which phase of the innovation process.

Applied implications

The typology of outside-in innovation based on dual boundary spanning allows managers to prioritize and make sense of their innovation portfolio by sorting innovation projects into discrete and relatively homogenous categories. As many firms have multiple innovation projects operating with different types of openness, the impact of resource allocation among these diversified projects on firms' innovation performance can be understood through the lens of the various types of openness. Firms' innovation portfolio, thus, can be managed with consideration of an important extra dimension (Klingebiel & Rammer, 2014). By using this typology, a firm can distinguish an overall pattern of openness among projects so that the relationships among external and internal factors that may influence on the performance of innovation projects can be better managed with respect to resource allocation and relationship leverage.

Limitations and future research directions

The types of innovations are operationalized in this study based on a dichotomous approach. Alternatively, a firm's reliance on external knowledge resources can also be measured quantitatively by calculating the number of knowledge suppliers and deciding on a cut-off value for high and low levels of reliance on external knowledge (see Tushman & Anderson, 1986). In fact, I tried with two different cut-off values, but the results were discarded because they had two obvious disadvantages: (1) the cut-off value is arbitrary and it was difficult to identify a sound justification for particular cut-offs; (2) the results using different cut-off values were extremely inconsistent, making it difficult to arrive at meaningful interpretations. Thus, I decided to rely on a binary measure that distinguishes whether a firm had external knowledge supplies or not.

However, the failure of using continuous measures to operationalize the variable in this particular case should not discourage the use of continuous measures in other cases. Continuous measures can be operationalized if the data allows in future research when a cut-off value can be justified and the results enable sense-making interpretations.

Readers must also be aware that the results of this study might not be perfectly replicated with data from a different era. For instance, it has recently become common for firms with a market orientation to involve users in co-creation, via the Internet and other mechanisms; for these firms, knowledge gleaned from user communities is regarded as a crucial external resource (Li-Ying & Salomo, 2013; Jensen et al., 2014). In such a case, the scope of external knowledge partners is enlarged; as a consequence, innovations that are based on an external initial idea and draw on co-creation with user communities can be redefined as type III (total outside-in) rather than type IV (focused sourcing). Similarly, data from another national context might not present the same patterns shown in this study due to different sociotechnical contexts. This suggests that the outside-in innovation typology is powerful only when the context is clearly defined.

Conclusion

Although prior studies have provided great insights on how open innovation has been adopted by industrial firms as an effective way leading to success, there are many underexplored issues with regard to how openness can be achieved. This study explores the nuances of different paths for outside-in innovation and proposes a unique typology that can be used with other research designs in future research to reveal a richer picture of what openness really means for firms' innovation process.

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Table 1: Examples and distributions of innovation types in Canadian innovation data (1945–1980)

Type II: **Complementary Learning** *Nr. of cases: 181* ***Example 1***: Atlas Turner INC. (Montreal, Quebec) in 1957 introduced asbestos cement pipe, which integrated pressure, gravity sewer, and building sewer; it was developed in-house but relied on technological know-how and product design from a British company and an American company. ***Example 2***: Union Carbide Canada Ltd. (East Toronto, Ontario) in 1964 introduced jet piercing machine for thermal drilling of primary blast holes for open pit mining; it was developed in-house but relied on equipment design of compressor component of system from a Canadian company in Woodstock, Canada.	Type III: **Total Outside-in** *Nr. of cases: 143* ***Example 1***: Beloit Sorel Walmsley (Pt. Claire, Quebec) in 1969 introduced inverform process of making board; it was developed externally and relied on licensed patents and engineering research from Beloit corporation, USA. ***Example 2***: Galt Equipment Ltd. (Montreal, Quebec) in 1975 introduced Galt "thermotrol" CO_2 clip-on refrigeration unit to provide cooling for frozen cargo in containers or truck; it was developed externally and relied on technology on liquid CO_2 from Liquid Carbonic Canada Ltd. in Montreal.
Type I: **Totally Closed Innovation** *Nr. of cases: 680* ***Example 1***: Cyanamid Canada Inc. (Montreal, Quebec) in 1954 introduced metal surfaced laminates, a decorative laminates having metal foil as surface layer; completely developed in-house, no reliance on external technology. ***Example 2***: Canadair LTD (Montreal, QUE) in 1958 introduced the 'tutor-trainer', a small military airplane; completely developed in-house, no reliance on external technology.	Type IV: **Focused Sourcing** *Nr. of cases: 205* ***Example 1***: McAvity Ltd. (St. John, New Brunswick) in 1961 introduced sigma-arc welding process for stainless steel fabricated valves; the innovative idea was originally developed externally but acquired by McAvity Ltd. And further combined with its internal technologies. The main supplier only provided welding equipment. ***Example 2***: Garrett Manufacturing Ltd. (Rexdale, Ontario) in 1966 introduced self-propelled vehicle system; the innovative idea was originally developed externally but acquired by Garrett and further combined with its internal technologies. The main supplier only provided two-speed 400 cycle motors and gear boxes.

Table 2: Descriptive statistics

Variables	Pioneering innovation	New-to-Canada	New-to-firm-only	Past experience	Firm size	Competition	Type I	Type II	Type III	Type IV
Pioneering innovation	1									
New-to-Canada	-0.793	1								
New-to-firm-only	-0.252	-0.269	1							
Past experience	0.071	-0.026	-0-031	1						
Firm size	-0.111	0.155	0.035	0.097	1					
Competition	-0.068	0.051	0.100	-0.003	-0.018	1				
Type I	0.092	-0.073	-0.101	0.060	-0.057	-0.041	1			
Type II	-0.029	0.047	-0.011	-0.041	0.101	0.010	-0.476	1		
Type III	-0.057	0.049	0.045	-0.020	-0.018	-0.018	-0.415	-0.154	1	
Type IV	-0.046	0.010	0.105	-0.023	-0.006	0.061	-0.512	-0.190	-0.166	1
Mean [b]	0.43	0.46	0.08	0.226	3.080	2.200	1.560	1.150	1.120	1.170
s. d.	0.495	0.498	0.269	0.456	1.529	1.821	0.496	0.357	0.323	0.375

N=1209

a. *Industry category* (SIC00, 01, 02 through 09) as control variables are not listed in the table.
b. For Types I, II, III and IV, it is coded as '1' if a particular type is false and '2' if it is true.

Table 3: Pioneering Innovations - Binary logistic regression for 1945-59, 1960-76, and 1977-80 [a, b]:

Variables	**Typel 1 (1945-59)**	**Typel 2 (1960-76)**	**Typel 3 (1977-80)**
Constant	1.674 (0.819)**	1.382 (0.321)***	1.173 (1.284)
Past Experience	0.298 (0.585)	0.249 (0.186)	0.309 (0.806)
Firm size	-0.073 (0.141)	-0.282 (0.053)***	-0.298 (0.245)
Competition	-0.198 (0.101)**	-0.077 (0.041)*	-0.121 (0.184)
Type I	(omitted)	(omitted)	(omitted)
Type II	-0.731 (0.426)* Odds ratio: 0.481	-0.038 (0.222)	-21.213 (16328.136)
Type III	-1.859 (0.623)*** Odds ratio: 0.156	-0.353 (0.233)	-1.628 (0.922)* Odds ratio: 0.196
Type IV	-0.810 (0.530)	-0.461 (0.207)** Odds ratio: 0.631	-0.169 (0.634)
-2 Log Likelihood	207.129	1048.531	86.493
Cox & Snell R^2	0.125	0.065	0.201
N =	*191*	*912*	*106*

a. ** p< 0.1; **p< 0.05; ***p< 0.01*
b. Coefficients for control variables *Industry category* (SIC00, 01, 02 through 09) are included, but not shown in the table.

Table 4: New-to-Canada Innovations - Binary logistic regression for 1945-59, 1960-76, and 1977-80 [a, b]:

Variables	Typel 1 (1945-59)	Typel 2 (1960-76)	Typel 3 (1977-80)
Constant	-1.605 (0.798)**	-1.354 (0.324)***	-1.900 (1.355)
Past Experience	-0.371 (0.566)	-0.125 (0.169)	0.242 (0.800)
Firm size	-0.021 (0.133)	0.223 (0.052)***	0.302 (0.249)
Competition	0.093 (0.094)	0.038 (0.041)	-0.009 (0.182)
Type I	(omitted)	(omitted)	(omitted)
Type II	0.540 (0.410)	0.110 (0.220)	21.661 (16242.691)
Type III	1.326 (0.524)** Odds ratio: 3.766	0.231 (0.227)	1.961 (0.927)** Odds ratio: 7.110
Type IV	0.336 (0.483)	0.080 (0.202)	0.446 (0.619)
-2 Log Likelihood	224.683	1062.877	87.223
Cox & Snell R^2	0.092	0.039	0.064
N =	*191*	*912*	*106*

a. * *p< 0.1; **p< 0.05; ***p< 0.01*
b. Coefficients for control variables *Industry category* (SIC00, 01, 02 through 09) are included, but not shown in the table.

Table 5: New-to-firm-only innovations - Binary logistic regression for 1945-59, 1960-76, and 1977-80 [a, b]:

Variables	Typel 1 (1945-59)	Typel 2 (1960-76)	Typel 3 (1977-80)
Constant	-3.787 (1.378)***	-3.584 (0.618)***	-8.991 (9.184)
Past Experience	0.427 (0.924)	-0.587 (0.411)	-82.385 (8755.279)
Firm size	0.140 (0.230)	0.130 (0.092)	3.597 (3.583)
Competition	0.271 (0.167)	-0.077 (0.041)*	1.309 (1.539)
Type I	(omitted)	(omitted)	(omitted)
Type II	0.615 (0.820)	-0.060 (0.464)	0.785 (12267.369)
Type III	0.943 (0.846)	0.530 (0.378)	-2.469 (17088.310)
Type IV	1.026 (0.775)	0.987 (0.311)*** Odds ratio: 2.683	15.835 (2523.703)
-2 Log Likelihood	87.508	443.058	5.433
Cox & Snell R^2	0.056	0.038	0.157
N =	*191*	*912*	*106*

a. * *p< 0.1; **p< 0.05; ***p< 0.01*
b. Coefficients for control variables *Industry category* (SIC00, 01, 02 through 09) are included, but not shown in the table.

Figure 1: Outside-in and inside-out process of open innovation (OI) revisited through the locus of innovation creation and commercialization (adapted from Bogers and West, 2010).

		Commercialization	
		Inside focal firm	*Outside focal firm*
Innovative idea created and developed	*Inside focal firm*	Closed innovation & possible outside-in OI (The focus of this article)	Typical inside-out OI
	Outside focal firm	Typical outside-in OI (The focus of this article)	Value capture out of reach by the focal firm

Figure 2: Multiple paths of boundary spanning, combining internal and external knowledge

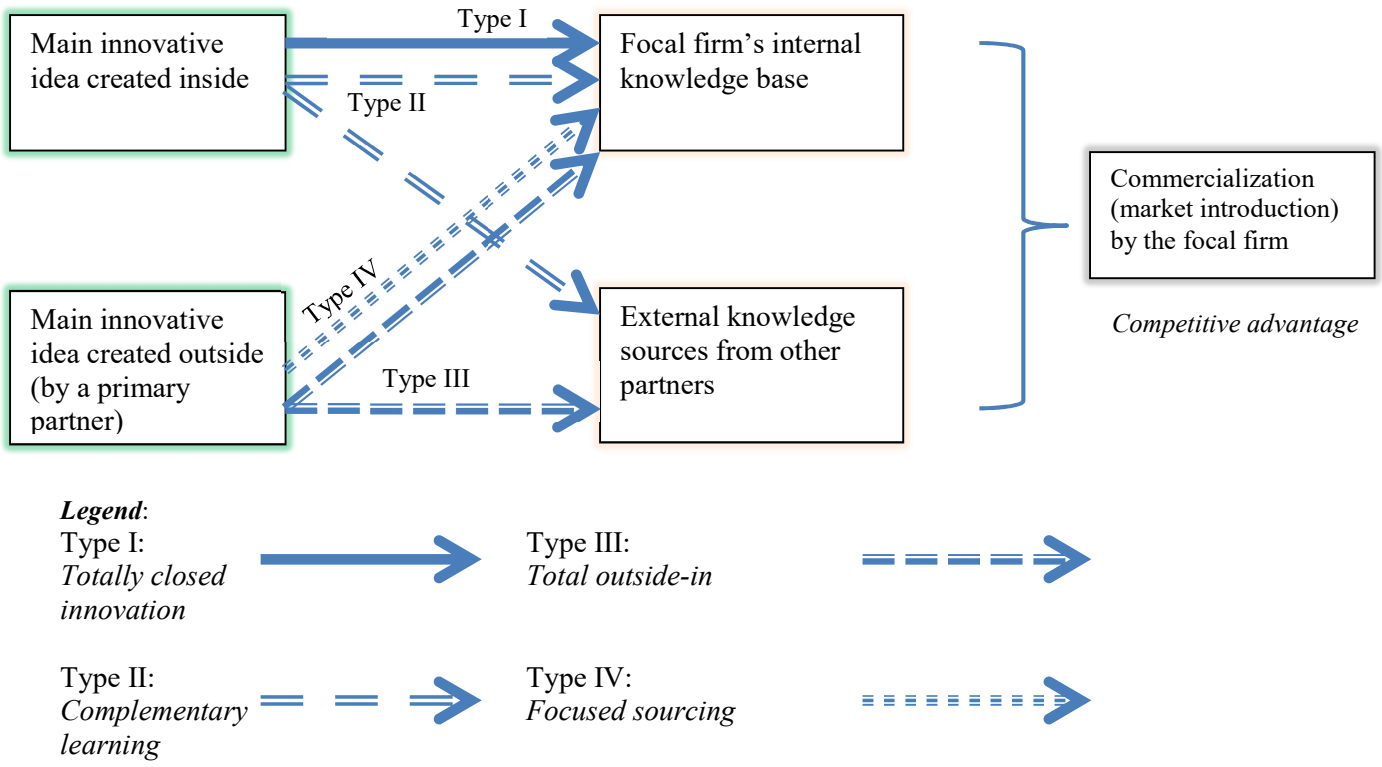

Figure 3: A typology of outside-in innovations

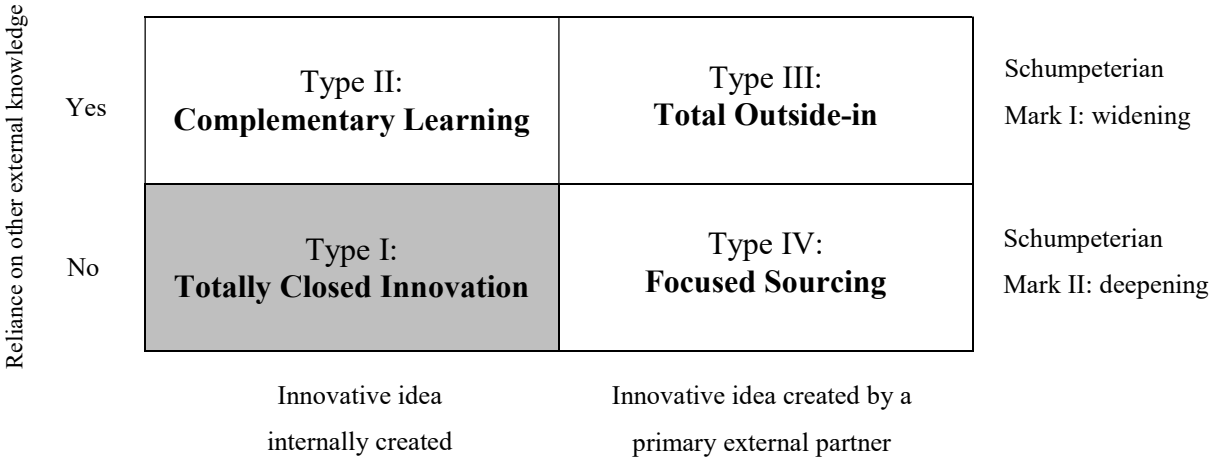

Figure 4: Yearly count distribution of innovation types (1945-1980) in the Canadian data