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COMPLEMENTARITY BETWEEN TECHNOLOGY MAKE AND BUY IN INNOVATION STRATEGIES: EVIDENCE FROM BELGIAN MANUFACTURING FIRMS

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ABSTRACT

This paper characterizes the innovation strategy of manufacturing firms and examines the relation between the innovation strategy and important industry-, firm- and innovation-specific characteristics using Belgian data from the Eurostat Community Innovation Survey. In addition to important size effects explaining innovation, we find that high perceived risks and costs and low appropriability of innovations do not necessarily discourage innovation, but rather determine how the innovation strategy is formulated. The paper then focuses on the determinants of the decision of the firm to produce technology itself (Make) or to source technology externally (Buy). One striking observation is that most firms use a combination of Make and Buy strategies. Small firms more likely restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine both internal and external knowledge acquisition in their innovation strategy. An interesting result that highlights the complementary nature of the Make and Buy decisions, is that firms for which internal information is an important information source for innovation are more likely to combine internal and external sources of technology. We find this to be evidence of the fact that in-house R&D generates the necessary absorptive capacity to profit from external knowledge acquisition. We also find that the effectiveness of different mechanisms to appropriate the benefits of innovations and the internal organizational resistance against change are important determinants of the firm's technology sourcing strategy.

Faced with increasing international competition, innovation has become a central focus in firms' long term strategies. Firms competing in global markets face the challenges and opportunities of change in markets and technologies. Given the less certain returns, management of risky sunk R&D expenditures has become even more of overriding importance for the survival of the firm. One aspect within innovation management is the optimal integration of external knowledge. In view of the increasing complexity and multidisciplinarity of research, even the largest and most self-contained of organizations requires information from beyond its boundaries. Innovation increasingly derives from a network of companies interacting in a variety of ways.

Ample theoretical and empirical research exists on firm and industry determinants of internal R&D. Dating back to Schumpeter's work, especially the relationship with firm size, market concentration, and technology characteristics such as appropriability and technological opportunities, has received the bulk of attention (see Cohen & Levin, 1989 for a review). But rather than trying to identify any single type of firm that is most innovative, the theoretical and a fortiori the empirical literature dealt less with the choice between different types of innovative strategies and sources of information. Little is known on complementarities and relationships among firms and other institutions that may facilitate innovation, as suggested by the literature on national innovation systems (Kline & Rosenberg, 1986; Freeman, 1987; Nelson, 1993).

The relationship between external knowledge acquisition and own in-house R&D activities, remains a complex issue. The theoretical literature that exists on this relation stresses the choice between external sourcing and internal development as substitutes, i.e. the classical MAKE <u>or</u> BUY decision drawing on transaction costs economics and property rights (Coase, 1937; Williamson, 1985; Arrow, 1962). In line with this theory Friedman, Berg and Duncan (1979) found evidence that external knowledge acquisition through the organization of joint ventures had a negative effect on internal R&D expenditures.

But, although the availability of external technology may discourage —and hence substitute for— own research investment by the receiver firms, there are also arguments to stress the complementarity between in-house R&D and external know-how, i.e. the MAKE <u>and</u> BUY decision. Own in-house R&D activities are often indicated as reducing some of the inefficiencies and problems associated with external acquisition, if only because it allows to modify and improve external acquisition. This requires however suitable internal structures to effectively absorb the externally acquired technology and overcoming the "Not-Invented-Here" syndrome. As a result, in-house R&D investment develops an "absorptive capacity" complementary to any external knowledge acquisition strategy (Cohen & Levinthal, 1990). While examining the critical success factors of 40 innovations, Freeman (1991) found external sources of technical expertise combined with in-house basic research that facilitate these external linkages to be crucial in explaining success of the innovation. Hence implying a strong complementary relation between in-house knowledge development and external knowledge acquisition. Similarly, firms performing in-house research would be the ones to draw most heavily upon the cooperative research associations set up after world war I in the UK. These research associations were intended to assist firms in technical matters and the expectation was that firms without any internal research facilities would draw most heavily upon these research associations. However, the research associations served as an important complementary source of scientific and technical information for firms performing in-house R&D. Additional evidence of this complementary relation comes from examining the payment streams for licenses where the flows are primarily between firms performing in-house R&D and not from firms that lack any in-house R&D capabilities to firms that have strong in-house R&D programs. Unfortunately most of this evidence on the complementary nature of these technology sourcing strategies is anecdotal. This paper intends to fill this gap in the literature by examining the innovation strategies of a large sample of Belgian manufacturing firms.

While external linkages considered so far, imply some active involvement or consent from the sending party, the difficulties in appropriating know-how allow for knowledge to diffuse and external know-how to be accessed without any explicit involvement from the sending party, even despite attempts from firms generating know-how to keep this proprietary (Arrow, 1962). By now an extensive theoretical literature, mainly in industrial organization, has developed around the effects of (involuntary) spillovers on own R&D (De Bondt, 1997). In this literature, spillovers may encourage or discourage own R&D investments depending on the innovation strategy chosen. In addition the appropriability regime will influence the innovation strategy selected (Teece , 1986).

While the literature as it stands today is only starting to unravel the complex phenomenon of linkages between internal and external innovation strategies, this paper presents an empirical analysis using firm level data of Belgian innovative firms. The empirical model is an extension of the classical studies on determinants of innovations while including external sourcing. The search is for company, technology or market characteristics driving the choice between making and/or buying technology.

We tackle the question of the firm's innovative activities and the complementarity between internal and external technology creation and acquisition in two steps. In a first step the firms decide whether or not to innovate, while in the second step the innovating firms decide on how to organize their innovation strategy. In addition to the standard explanatory variables like size and measures of technological opportunity, the model includes variables constructed from questionnaire responses of the firms. These variables relate to issues such as information sources for innovation, goals of the innovation process, protection of innovations and obstacles to innovation activities. An interesting result is that the absence of a need to innovate, due to disinterest by customers or as a result of previous innovations, is an important determinant of the non-innovative character of firms. On the other hand, high perceived risks and costs of innovation and low appropriability of results do not necessarily discourage innovation, but rather determine how innovation is organized.

The focus of the second step of the analysis is precisely on how innovation is organized. In this section we single out the determinants of the decision of the firm to acquire technology by itself (Make decision) or to source externally (Buy decision). One striking observation is that most firms use a combination of both the make and the buy technology strategies which exemplifies the need for more research into the complementary nature of these strategies. Another interesting result is that firms that rely on internal information sources for the innovation process are more likely to combine the make and buy option instead of solely developing innovations in-house. Our results thus seem to support the absorption capacity view of in-house research. Appropriability conditions as determined by the effectiveness of different protection measures also influences the optimal sourcing strategy of the firm. The actual decision to acquire technology externally, either exclusively or in combination with internal development, is determined by the relative effectiveness of different mechanisms of protection of technological innovations.

The remainder of the paper is organized as follows. In the next section, the literature is briefly reviewed and some hypotheses are formulated. Section 3 discusses the data and the questionnaire. In Section 4, the results of our two step analysis are presented. We conclude in Section 5, discussing implications and further lines along which to develop this research.

LITERATURE AND HYPOTHESES

Who Innovates?

The innovation process consists of a complex sequence of decisions. We structure the decision of a firm on how to innovate as a two step process. First, the firm decides whether or not to innovate and second, the firm decides which innovation strategy to develop and how to acquire the necessary technology to accomplish its innovation goals. For this first step, ample empirical and theoretical studies exists on firm and industry characteristics influencing firm's or industry's innovativeness.

Innovation and Size. The most classical research topic, dating back to Schumpeter, is the relationship between firm size and innovation. Are there any scale advantages to innovation for large firms or does innovation rather emerges in small entrepreneurial firms? The results, are mixed but seem to suggest that the tendency between innovativeness and size is positive, but not necessarily linear, with evidence for a U-shaped relationship (see Kamien & Schwartz, 1982; Cohen & Levin, 1989 for a review). In any case, the size relationship depends on industry characteristics. Acs and Audretsch (1987) for instance find large enterprises to be more innovative in sectors with high concentration and barriers to entry, while small firms are more innovative in sectors with low concentration in newly emerging or growing technologies.

Hypothesis 1a:After controlling for industry characteristics, small firms tend to be more innovative than medium sized firms.
Hypothesis 1b:After controlling for industry characteristics, large firms tend to be more innovative than medium sized firms.

Innovation and Industry Characteristics. A second, again Schumpeterian, research topic is the relationship with market power. Expected future market power serves as an incentive to innovate while ex ante market power generates financial means and reduces risk levels. However ex ante competitive pressure can be an incentive to innovate and obtain future market power. With no theoretical clear-cut relationship, the empirical results are ambiguous (e.g. Bozeman & Link, 1983). An inverted U-shaped relationship, with not too little and not too much competition in the industry, seems most conductive to innovation (Scherer, 1967). But also here the relationship is strongly determined by technology characteristics, such as appropriation conditions.

As already indicated industry/technology characteristics are a critical determinant of innovative behavior. In many empirical studies, including industry dummies is important for the explanatory power of the estimated relationship. Several industry dimensions are of importance here. First there is the scope for future demand, i.e. the classical Schmookler (1962) hypothesis. Not only the size and growth of the market matters, but also the willingness to pay for new or improved products. Next there is the dimension of whether technology exhibits opportunities for innovation. Scherer (1965) already identified technology classes on the basis of this. Levin and Reiss (1984) use more specific survey-information to proxy for technological opportunity such as different sources of information, and links with science. Also cumulativeness of knowledge can be important: to which extent can current innovations build further on previous R&D (Breshi, Malerba & Orsenigo, 1996). Included in here is the role of technology life cycles and emergence of dominant designs or technology trajectories.

Innovation and Appropriability. Finally, the incentives to innovate will depend on the extent to which the results from innovative activities can be appropriated or easily diffuse within or across industries. Next to legal mechanisms such as patents or brand names, the firm can strategically protect its information through secrecy, the complexity of the technology or lead time over competitors (Mansfield, 1985). In the literature we find two opposing effects of low levels of appropriation. On the one hand, a low level of appropriation might lead to a disincentive effect. Firms reduce their in-house investments in research and development below the efficient levels because they are unable to appropriate the full benefit of their investment (Arrow, 1962; Spence , 1984). On the other hand, however, low levels of appropriability lead to high spillovers between firms. In order to capitalize on these spillovers, firms need to develop sufficient "absorptive capacity" which implies more in-house investment in research and development (Cohen & Levinthal, 1990).

Hypothesis 2: If the benefits of innovations are hard to appropriate, firms are less likely to be innovative.

How do Firms Organize Innovation?

Sources of Knowledge and Innovation Strategies. The survey data used in the empirical analysis allow us to include many of the cited dimensions critical to explain the firm's decision to innovate or not. But in order to obtain a better understanding of the complementarities and relationships among firms and institutions, it is important to understand how innovation is induced by strategies combining internal and external sources. Most of the existing theoretical literature concentrates on the exclusive choice between internal sourcing and external sourcing of technology. On the combination between internal and external sourcing the theoretical literature is very scarce, while the empirical literature provides mainly indirect evidence on the importance of the phenomenon (Veugelers, 1997).

Insert Table 1 about here

Table 1 summarizes different potential sources of information for the innovation process. Given these information sources, we can distinguish between the different strategies that can be employed to acquire and internalize technological knowledge: the firm's *innovation strategy* (see Table 2). A firm can rely on a combination of three different strategies to engage in innovation. First, firms can do R&D in-house and develop their own technology, which we see as the firm's MAKE decision. A second alternative strategy is to acquire technology externally, the BUY decision. We identify two alternative buy decisions of the firm. On the one hand, the firm can acquire new technology which is embodied in an asset that is acquired such as new personnel or (parts of) other firms or equipment. On the other hand, the firm can obtain new technology disembodied such as in blue prints through a licensing agreement or by outsourcing the technology from an R&D contractor or consulting agency. A third, more hybrid form of obtaining and developing new technology is through cooperative agreements between firms or other research institutions. A final sourcing strategy is to absorb existing technology without any explicit involvement from the innovator. Freely available information or involuntary spillovers from innovators can be used by companies in their innovation process (see Table 1). However, it will be impossible to distinguish this strategy from the firm's make decision in our sample.

Insert Table 2 about here

Make or Buy: Theory and Hypotheses. Building further on the general literature on make or buy decisions, i.e. transaction cost economics (Williamson, 1985) and property rights theory (Grossman & Hart, 1986), the theoretical framework to explain R&D outsourcing stresses the advantage of tapping existing often more specialized knowledge if available. This leads to time gains and lower innovation costs to the extent that economies of scale in R&D can be more efficiently exploited. However technology outsourcing may create considerable transaction costs, ex ante in terms of search and negotiation costs and ex post to execute and enforce the contract. Typically, costs are incurred because of a control loss on technological leakage or due to supplier opportunism. The hold-up problem results in underinvestment of the supplier, where the latter has too little incentives to make specific investments whose rents can be appropriated by the buyer. Next to asset specificity, the typical uncertain nature of R&D projects exacerbates these problems. Hence, R&D contracting is more likely to occur for generic, non-firm specific R&D that allows for specialization advantages, such as routine research tasks like materials testing, and process rather than product innovations (Mowery & Rosenberg, 1989). In addition we expect external technology sourcing when the appropriation regime is tight as it is in the pharmaceuticals industry (Teece, 1986) and when assets complementary to the technology are in competitive supply such that the small numbers bargaining hazards are minimized (Pisano, 1990). Rather than trying to save on these contracting costs through internal sourcing, the agency literature suggests as a solution a careful design of control and incentive mechanisms. Instead of a hierarchical governance structure, more hybrid type of contracts that leave enough property rights to the seller, may mitigate the typical negative effect of control on incentives (Ulset, 1996).

One such alternative governance structure is a more cooperative type of agreement that is increasingly observed in practice. While this cooperative R&D allows for sharing of costs and risks and the exploitation of synergies from complementarities between partners, and provides access to external technologies and in some cases governmental support, it may also be less vulnerable to transaction costs as compared to contracting. It not only allows for a better control of technology transfers and internalization of spillover effects, but also the inherent reciprocity relationship between complementary partners minimizes opportunism. However, information asymmetries and the uncertain nature of R&D may also here endanger the exploitation of cooperative benefits. But rather than turn to contracts to minimize the incentives for opportunism in cooperation, firms can select partners where reputation matters more and where complementary is maximized (Gulati, 1995). Maintaining in-house R&D activities remains important to secure the firm's bargaining position and efficiently absorb results from collaborative ventures (Contractor, 1983; Gans & Stern, 1997). This leads to suggest a complementarity between make and cooperation.

Instead of discussing make or buy or cooperate as substitutes, the potential for combining internal and external sourcing modes as complementary innovation strategies should not be ignored. Although one strategy may substitute for the other, combining internal and external sourcing creates extensive scope for complementarities. In-house R&D may serve to modify and improve external technology acquisitions, at least if the in-house organizational structure exhibits a willingness to absorb and overcome the "Not-Invented-Here" syndrome. (Harrigan, 1985; Cohen & Levinthal, 1989).

Hypothesis 3: Firms for which internal information sources are important, are less likely to exclusively source externally. They are more likely to combine internal and external technology sources.

Hypothesis 4: Firms characterized with a high resistance to externally induced change are less likely to use an external technology sourcing strategy.

Following the literature, large firms can be expected to be less likely to buy to the extent that scale advantages in R&D can be realized in-house. Furthermore, to the extent that large firms have own in-house R&D with better absorptive capacities, they are better tuned to benefit from external sourcing (see Gambardella, 1992 and Henderson & Cockburn, 1996 for evidence on this from the pharmaceuticals industry). The specific problems that small and middle sized firms encounter in establishing external linkages are discussed in Rothwell and Dodgson (1991). Pisano (1990), however, found that bio-tech companies with more R&D experience rely more on internal sourcing. This result is explained by the author in a behavioral-theory-of-the-firm framework where bounded rationality prevents firms from making the necessary adjustment and continue to behave according to routines developed in the past.[2]

Hypothesis 5: Large firms are <u>less likely</u> to Buy technology as their sole innovation strategy.

Teece (1986) stresses the importance of the appropriability regime in the choice of governance structures. When appropriability is high, firms are willing to develop technology internally and to sell their technology to other firms to appropriate the benefits from innovating. Hence, firms that decide to acquire technology externally, are more likely to acquire this technology in disembodied form such as through licensing agreements or R&D contracts. If internal and external technology sourcing strategies are complementary, we expect to observe the combination more when innovations are easier to appropriate. High spillover environments quickly erode a firm's technological advantage. In that case firms will develop specialized complementary assets internally to protect their technology and firms that decide to acquire technology externally, acquire this technology in embodied form through the acquisition of other firms or by attracting specialized personnel.

Hypothesis 6: If the benefits of innovations are easier to appropriate, firms are more likely to combine internal and external technology sourcing strategies.

Hypothesis 7: If the benefits of innovations are easy to appropriate, firms are more likely to acquire technology in disembodied form, while if the benefits of innovations are hard to appropriate, firms are more likely to acquire technology in embodied form.

There exists little explicit theory on the determinants of embodied or disembodied technology acquisition. But one could still hypothesize that if legal protection of innovations is tight, firms are more likely to be able to obtain technology in disembodied form in arms-length transactions. If innovations are easier to protect through strategic measures such as secrecy, lead time, or complexity of the product or process, firms are more likely to find technology tied to complementary assets and acquire technology in embodied form. Our results are intended to stimulate discussion and further research into these determinants.

SAMPLE

The data used for this research are innovation data on the Belgian manufacturing industry that were collected as part of the Community Innovation Survey conducted by Eurostat in the different member countries in 1993. The survey intended to develop insights into the problems of technological innovation in the manufacturing industry and was the first of its sort organized in many of the participating countries. A representative sample of 1335 Belgian manufacturing firms was selected and a 13-page questionnaire sent out to them. The response rate was higher than 50% (748). The researchers in charge of collecting the data also performed a limited non-response analysis and concluded that no systematic bias could be detected (Debackere & Fleurent, 1995).

The sample is detailed in Figure 1. In the first branch of Figure 1, firms that innovate are distinguished from those who do not innovate based on their answer on the question whether they innovated in the last two years and returned a positive amount spent on innovation: 60% of the firms in the sample claim to innovate, while only 40% does not. This number is in line with the survey results from other EC countries: an average 50% of all EC companies described themselves as innovative (Source: Eurostat, Statistics in Focus, 1996-2).[3]

Next we distinguish how firms acquire and develop new technology: the make or buy decision. On the one hand firms that develop their own technology can do this in-house through own R&D spending. On the other hand the firms can acquire technology through external means. With the exception of the involuntary spillover strategy, different external sourcing strategies could be identified.[4] In order to reduce the number of categories of external technology acquisition, we grouped the different strategies either as "disembodied" technology acquisition or as "embodied" technology acquisition. In the former case, the asset acquired is the technology itself such as in licensing agreements, R&D contracting, or consulting services. In the latter case the technology is embodied in the good or asset acquired, such as new personnel or (part of) other firms. We ignored the "embodied" purchase of equipment, mainly because too many firms responded positively on this item. Probably not all of them interpreted the question as buying equipment with the explicit purpose of obtaining new technologies and as an alternative to developing the technology internally.

Insert Figure 1 about here

In the sample most of the innovating firms both make and buy technology (73%) while 17% only makes its technology in-house and the remaining 10% only buys. This result demonstrates the importance of linkages between internal and external sourcing or a complementarity between the make and buy decision of the firm. This complementarity is even more striking between Make and Cooperate. One important note is that we never observe firms cooperating while not performing any in-house R&D, which partly follows from the definition of cooperation in the survey.[5] If the firm is observed to cooperate actively, it implies that this firm spends on R&D internally. Given this joint occurrence, we will concentrate the external sourcing decision in the empirical analysis on the Buy options of the firm. The cooperate option is more fully analyzed in a companion paper.

When buying technologies, exclusively or in combination with making technologies, firms mostly combine disembodied and embodied purchases, especially when combining with own R&D and cooperation. Surprisingly, exclusive disembodied purchase of equipment, most frequently discussed in theoretical modeling, is in the dataset almost ignorable.

The following Table reports the more disaggregated external technology acquisition data for the sample. It is especially interesting to note that firms that also develop their own technology (make) are more likely to rely on external R&D contracts. This is again an indication that these relations are complementary: internal technology development increases the value of any externally acquired technology, especially when this technology is disembodied and needs to be assimilated by the organization to exploit its value.

Insert Table 3 about here

The size effects, formulated in Hypotheses 1 and 5 can be appreciated by looking at the following Table 4. Large firms are more likely to innovate. Of the firms with less than 50 employees, only 37% innovate compared to 60% of the firms in the whole sample. Small firms that are innovative are more likely to restrict themselves to a simple innovation strategy. Of the firms only developing technology in-house, 76% have less than 250 employees, while 74% of the firms that only source technology externally have less than 250 employees. Large firms seem to choose more for the combination of innovation strategies. Note however that we still need to control for industry and technology characteristics in a multivariate analysis to establish a more robust result.

Insert Table 4 about here

Besides characterizing the innovative strategies of the companies along the make-buy dimension, the questionnaire also allows to assess other important dimensions of the innovation process. The respondents were asked to rate the importance to their innovation strategy of different information sources for the innovation process, goals for innovation, protection of innovations and obstacles to innovation. Firms had to rate their answer on a 5-point Likert scale (from unimportant (1) to crucial (5)). In order to manage the answers on these many questions, we aggregated the answers by summing the scores on related variables and rescaled the total scores to a number between 0 and 1 for comparability. For a summary of the questions and categories we selected, see Appendix. Firms that did not perform any innovative activity were also asked to answer the questions on firm characteristics (sales, personnel, ...) and the questions on the obstacles to innovation. Table 5 represents the descriptive statistics and correlation matrix for the total sample. Table 6 summarizes the descriptive statistics for the innovating firms. We should note the high correlation between some of the variables relating to obstacles to innovation.

METHOD AND RESULTS

We estimated several alternative models, but only report the results of the most representative ones. The results discussed here are the ones that remained significant under any of the alternative specifications.[6]

Innovation Decision.

In this section we study the innovation decision of the manufacturing firms in the sample in a multi-variate analysis. Given that both innovating and non-innovating firms responded to some parts of the questionnaire, we can attempt to discriminate between innovators and non-innovators in the sample. We use a Logit model where the dependent variable is 1 when the firm claims to innovate (and specified a positive innovation budget). The independent variables used in all the models are detailed in the Appendix.

The results of the estimation are presented in the following Tables. The high Chi-squared of the model indicates the high joint explanatory power of the independent variables.

Insert Table 7 about here

The coefficients in Table 7 are the estimated partial derivatives of probabilities with respect to the vector of characteristics. They are computed at the means of the independent variables. The coefficient tells us how much the probability that the firm innovates increases with an increase in that independent variable, holding the other independent variables constant. The signs of most of the coefficients are as expected. Large firms (more than 500 employees) are more likely to innovate (SizeL). For small firms (less than 50 employees) (SizeS) we find that the probability of being an innovating firm is lower. This confirms Hypothesis 1b but seems to reject Hypothesis 1a (cf. infra). Both size coefficients are significant, indicating a non-linearity in the size relationship.

Interesting is the highly significant coefficient of the export intensity of the firms (Expint). All else equal, a firm that exports 10% more of its production has a 3.74% higher probability of being an innovating firm. Competitive pressures in the international markets could account for the fact that constant innovation is the only way to hold on to international market share. Somewhat counter intuitive at first sight, we find that firms that find high risks and high costs an obstacle to innovation, are actually more likely to innovate (OBSTcost). Put differently, high risks and costs of innovation do not deter firms from innovating, on the contrary it seems. This result suggests that this variable seems to capture awareness to obstacles rather than effectiveness in blocking innovative purposes. This observation will be important in understanding how firms actually organize their innovation strategy (see below). The lack of technological information (OBSTinfo) seems to have a similar effect on the innovation decision. Lack of opportunities to innovate (OBSTlack) has the expected sign, but does not show up significant in the decision whether or not to innovate. More important in the decision to innovate is the perception of a need for innovation (OBSTneed), whether a low willingness to pay for innovations of the customers or the fact that the firm is still profiting from previous innovations. This variable has the expected negative effect on the decision to innovate.

Resistance against externally induced change (OBSTresist) has the expected effect on the decision to innovate. The "Not-Invented-Here"-syndrome limits the ability of firms to engage in innovative activities. However, we do expect that companies that have a high resistance against change but innovate nevertheless, will also use different innovation strategies as formulated in Hypothesis 4.

The expected effect of low appropriability of innovation benefits was ambiguous (OBSTimit). On the one hand high spillovers discourage investments in research and development. On the other hand, these spillovers might be complements to in-house R&D and actually stimulate innovation. The regression results seem to support the absorptive capacity of spillovers and as a result reject Hypothesis 2. Given that spillovers seem to stimulate innovation, we should also expect appropriability conditions to affect the type of innovation strategy used (see below).

The typical high-tech industries, especially Chemicals and Electric(onic)s, have the expected positive coefficients and are highly significant. The traditionally low-tech sectors, like textiles, wood & paper are not significant. This result is in line with most other studies which found strong industry effects. Here industry dummies proxy for demand and supply conditions within the industry. Including these proxies, such as concentration, technological opportunities and appropriation at the industry level, did not improve the results of the simple industry dummies. In any case, these variations to the basic model seem to suggest that the inclusion of industry variables does not seem to influence the effects of company characteristics.

Given the discontinuous nature of the size variables (SizeS and SizeL), it is interesting to look at the marginal effects for the two values of these variables. The results are summarized in Table 8 where a split regression was performed for both values of SizeS and SizeL. As expected, the marginal effects of the other independent variables are much more pronounced in explaining innovation for the small firms (SizeS). Export intensity is much more important in explaining innovation by small firms than it is for larger firms. Also the industry dummies increase in importance in explaining innovation of small firms. This is an indication that the innovativeness of small firms depends strongly on the industry characteristics, something that Acs & Audretsch (1987) also found. It might also explain the lack of direct support for Hypothesis 1a if the random sample contains relatively more small firms in low tech sectors.[7] The explanatory power of the independent variables other then size is rather limited for the large firms (larger than 50 employees), and a fortiori for the biggest firms (larger than 500, SizeL).

Insert Table 8 about here

An alternative measure of goodness of fit for the Logit models compares the frequencies of actual and predicted outcomes. The predicted outcome is the one that has maximum probability. The model predicts 77% correctly (565 of 734). A naive model would predict 439 out of 734 correctly or only 60%. Our model thus has some predictive power beyond a naive guess. Next we restrict the sample to the firms that do innovate and analyze how they organize their innovative activities along the make versus buy decision.

Technology Make or Buy Decision

We consider three choices of how the firm can organize its innovation. First firms can develop new technology themselves: the **Make** decision. Second, the firms can rely on external sources for their technology, or can **Buy** the technology. This category includes licensing agreements, external R&D contracts, consulting agencies, acquiring firms or parts of firms, or attracting qualified personnel. The third possibility, of course, is that the firms use both the **Make and Buy** strategies. As we saw before, this is the most prevalent case (283 out of 401 observations). Since we do not focus on the cooperate option, we drop the 38 observations from the companies that make & cooperate, who could not be included in the exclusive make, nor in the combination of make & buy, since they are not active in buying. The buy & cooperate strategy is never observed since cooperate is always associated with make. We tested on a subset of the sample with firms that make and/or buy for differences between those who do and do not cooperate, but found no important differences. This make & buy option includes both those who do and do not cooperate. In addition we need to drop 38 observations due to missing values on some of the independent variables.

We estimate a multinomial logit model with three choices: make only, buy only, and, make and buy. The joint explanatory power of the independent variables is again high given the high Chi-squared value for the estimated model. When there are more than two outcomes for the dependent variable, it is more useful to look at the marginal effects of the independent variables on the probability of each of the choices. The following Table presents the results for the full model.

Insert Table 9 about here

As suggested by Hypothesis 5, larger firms are more likely to both make and buy technology while small firms are more likely to source technology externally (SizeS, SizeL). Small firms cannot generate the same economies of scale as larger firms when performing research internally. As a result they restrict themselves to acquiring technology externally and are less likely to choose for the combination strategy.

The results of the regression seem to support Hypothesis 3, where firms that generate more useful information internally (INFOint) are more likely to combine the internal and external sourcing strategies. This provides evidence in favor of the absorption capacity hypothesis of in-house research and development. In order for firms to take advantage of any externally acquired technology they need to perform some internal research to facilitate a smooth assimilation of the technology.

Resistance against externally induced change (OBSTresist) may capture the effect of the "Not-Invented-Here" syndrome. Firms that experience this syndrome are clearly less likely to rely on an external sourcing strategy. Hypothesis 4 formulated this intuition and the data agree that within manufacturing this is an important determinant of a firm's innovation strategy, reducing the probability of exclusive external sourcing.

The effect of low appropriability is captured by four variables: OBSTimit, PROTlegal, PROTstrat and PROTtime. A high score on OBSTimit indicates that the firm believes that imitation of innovations is relatively easy. A high score on PROT-variables relates to the beliefs of the firm about how effective legal or strategic protection or protection through lead-time on competitors is. A high score implies high (awareness of) appropriability. The only variables that are significant are PROTlegal and PROTtime. Both variables indicate that if appropriability is strong or if firms are more aware of the importance of appropriation, they are less likely to opt for an exclusive external sourcing strategy. The results are consistent with Hypothesis 6. The significance of legal protection might be a result of two effects. First when legal protection of technology is effective, more firms are willing to develop this technology internally and then transfer this technology while extracting some rents. Secondly, given the complementary nature of in-house R&D, the acquiring firm needs to perform some internal development to integrate this new technology. Thus combining the make and buy strategy is more efficient, relative to exclusive make or buy. In order to appropriate the benefits of innovation through lead-time on competitors, the firms avoid external sourcing and rely on in-house R&D. avoid spillovers through fully relying on in-house research to create lead-time.

Firms who consider costs and risks as important obstacles to innovation (OBSTcost), try to combine developing the technology and acquiring some parts externally to either strategy alone. Firms thus try to overcome this obstacle by combining internal and external sourcing. This is a partial explanation for the fact that we found that high costs and risk of innovating do not discourage innovation by the firms per se, but rather determines how these firms set up their innovation strategy.

An interesting result is the highly significant coefficient of INFOcomp. If competitors are an important source of information for the innovation process, firms are more likely to source knowledge externally. In particular, firms are more likely to only innovate through a Buy strategy. External knowledge acquisition strategies by competitors are easier to observe and imitate than internal development efforts. Which external technology sourcing strategies competitors use could be important information for the firm's own innovation activities. As a result we expect this variable to have a positive effect on the external acquisition strategies of the firm.

The industry dummies indicate that firms in the chemical sector and the electrical equipment sector, as innovation intense sectors, are unlikely to rely solely on an external innovation strategy. These high tech sectors are more likely to be able to take advantage of complementarities between internal and external technology sources. Other variables relating to technological opportunities within the industry were not significant. Our estimates were not sensitive to dropping these variables from the model (see Table A1 in the Appendix).

Although the model has high explanatory power, the goodness of fit when tabulating actual against predicted values underpredicts the make only and buy only decisions considerably. A naive model would assign all the observations to the Make and Buy category. This would result in 73% correct predictions (264 out of 363). The model as presented increases the predictive power to 77%. Nevertheless the significant coefficients in the model estimation indicate which variables are important in the organization of the firm's innovation strategy. Next we analyze the external technology sourcing decisions of the firms in our sample and provide some determinants of the organization of technology transfer between organizations.

External Technology Sources: Embodied or Disembodied Technology Acquisition

We can classify technology acquisition in two broad categories. First the organization can acquire new technology that has to be assimilated by the organization. In that case we say that the technology is **disembodied**. Disembodied technology acquisition strategies include licensing, R&D contracting and the use of technology consulting agencies. Second, new technology can be acquired that is embodied in the good or asset that is acquired. We call this **embodied** technology acquisition. Such strategies include acquisition of firms or attracting qualified personnel. To analyze the different ways that firms can structure their external innovation activities, we restrict the sample to all those firms that are actually engaged in external technology acquisition and classify them as organized to acquire technology embodied, disembodied or both. There exists very little theory to formulate hypotheses on the variables that influence the decision of the firm to opt for embodied or disembodied technology. The results reported here should therefore be interpreted as predictions useful for further elaborations.[8]

The coefficients of the variables in the estimated model are again jointly very significant. Table 10 presents the marginal effects of the independent variables on the probability of the respective choices.

Insert Table 10 about here

Larger firms are less likely to acquire embodied technology while small firms are more likely to acquire embodied technology (SizeS, SizeL). Smaller firms that do acquire technology externally are more likely to accomplish this through taking over relevant parts of other firms or attracting specialized personnel instead of assimilating disembodied technology, for which they lack the required absorptive capacity to fully capitalize on this disembodied technology.

An important determinant of the decision to acquire technology in embodied or disembodied form is the type of protection that is available. When the firm gets better protection from secrecy, lead time or complexity, it is less likely to acquire disembodied technology (PROTstrat). If on the other hand legal protection is tight (PROTlegal), the firms that acquire technology externally are more likely to acquire it in disembodied form. Again if legal protection is tight, more firms offer technology licenses or it is easier to write specific contracts for the delivery of technology. If strategic protection is tight however, firms offering technology try to appropriate any rents through embodying the technology within complementary, but harder to replicate assets. This is simply a restatement of Hypothesis 7 for which we find support in the data.

When innovation costs and risks are perceived to be high, the firm is less likely to acquire disembodied technology (OBSTcost). Here again the perceived costs and risks of innovation influences the innovation strategy of the firms.

An important variable related to the complementarity of internal and external innovation activities is whether or not the firms develop knowledge internally (Make). In-house development of technology clearly enhances the ability of the firm to realize benefits from disembodied technology acquisition. The result that in-house development and disembodied technology acquisition are strongly related, while the relation with embodied technology acquisition is the opposite, is interesting food for thought on the question of the complementarity between internal and external knowledge acquisition strategies.

We can again check the choices predicted by the model against the actual choices in order to get an idea of the predictive power of the model. The naive model would classify all observations as combining the embodied and disembodied technology strategies. This model would predict 130 out of 303 correctly (43%). Our model increases the predictive power to 50%.

CONCLUSIONS AND EXTENSIONS

The relationship between external linkages and in-house R&D activities, remains a complex issue. The literature that exists on this stresses the choice between external sourcing and internal development as substitutes, i.e. the classical MAKE or BUY decision drawing on transaction costs economics and property rights. But, although the availability of external technology may discourage —and hence substitute for— own research investment by the receiver firms, there are also arguments to stress the complementarity between in-house R&D and external know-how, i.e. the MAKE and BUY decision. Own in-house R&D activities are often found to reduce some of the inefficiencies and problems associated with external acquisition, if only because it allows to modify and improve external acquisition. This requires however suitable internal structures to effectively absorb the externally acquired technology and overcoming the "Not-Invented-Here" syndrome.

We tackle the question of the firm's innovative activities and the complementarity between internal and external technology creation and acquisition in two steps. In a first part we analyze the determinants that distinguish innovating firms from non-innovating firms. In addition to the standard explanatory variables like size and measures of technological opportunity, the model includes variables constructed from questionnaire responses of the firms. An interesting result is that high perceived risks and costs of innovation and low appropriability of results do not necessarily discourage innovation, but rather determine how innovation is organized. Also size is very important in explaining innovative activities, where especially the biggest firms have the highest likelihood of innovating.

The focus of the second step in the analysis is precisely on how innovation is organized. In this section we single out the determinants of the decision of the firm to develop technology by itself (Make decision) or to source externally (Buy decision). One striking observation is that most firms use a combination of both the make and the buy technology strategies. Small firms have a higher probability of using an exclusive make or buy strategy and are less likely to combine these technology sourcing strategies. Large firms are more likely to combine both the make and buy options. Firms relying on internal information sources for the innovation process are more likely to combine the make and buy option. Our results thus seem to support the absorption capacity view of in-house research. The actual decision to acquire technology externally, either exclusively or in combination with internal development, is determined by the effectiveness of different mechanisms of protection of technology. Strong legal protection or appropriability through lead-time on competitors lead the firms to reduce the probability of an exclusive external knowledge sourcing strategy. Internal organizational resistance against externally induced change will also lead to less exclusive external technology sourcing.

In the future we hope to further strengthen these results. First, a panel data set would allow us to eliminate the firm specific fixed effects which might be driving these results. Second, an important dimension of evaluating alternative organizational structures is assessing their technological performance. In order to accomplish this, good performance measures for technological innovation need to be constructed. Third, the fact that we only have information on the firm's innovation strategy but no information about the project level limits the conclusions we can draw about the complementarity of the make and buy innovation strategies. Ideally we would like to have information on the strategy employed to accomplish a specific project and whether the firm developed parts of the technology in-house while outsourcing other elements, or whether it restricted itself to a strategy of in-house development or external sourcing. Given some case evidence, we feel confident that even at the project level we will observe a strong complementarity between the technology sourcing strategies.

Finally we can compare the results for the Belgian case against those for other countries that have participated in the Community Innovation Survey. Divergence in results could be due to different firm populations or industry structure, but more interestingly they could also be due to differences in the innovation policies within these countries and regions. This would allow us to formulate some policy recommendations to stimulate innovation within lagging sectors and/or regions and improve existing innovation policies.

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Appendix

AGGREGATED CATEGORY FOR RESEARCH	QUESTIONNAIRE QUESTIONS Rate each of the following from 1: unimportant to 5: crucial for innovation activities.
Information Source for Innovation	
Internal Information Sources (INFOint)	information within the company information within the group
External Information Links	information from suppliers raw materials/components information from equipment suppliers information from customers
Information from Competitors (INFOcomp)	information from close competitors
Scientific Information (INFOscience)	information from Universities information from Public Research Institutes information from Technical Institutes
Freely Available Information	patent information specialized conferences, meetings, publications trade conferences, seminars
Goals of Innovation Activity	
Cost Reduction, Efficiency Improvement (GOALcost)	increasing flexibility lowering wage cost lowering material usage lowering energy usage lowering design cost lowering set up time lessen environmental effects improve work environment and/or on the job security
Quality Improvement (GOALqual)	increase product quality replace older products
Market - Product Line	increase main product line increase secondary product line maintain market share accessing new markets (national, in EC, North America, Japan, others)
Protection of Product and Process Innovations	
Legal Protection (PROTlegal)	patent protection registration (brands, copy rights,...)
Strategic Protection (PROTstrat)	secrecy complexity of product or process design
Timing	lead time on competitors
Obstacles to Innovation	
Costs and Risks (OBSTcost)	risks too high no suitable financing available high costs of innovation pay-back period too long innovation cost hard to control uncertainty about introduction times
Lack of Opportunities (OBSTlack)	lack of external technical services few opportunities for cooperation lack of technological opportunities
No Need for Innovation (OBSTneed)	no need for innovation because of earlier innovations little interest for innovations by customers
Lack of Information (OBSTinfo)	lack of qualified personnel lack of personnel to innovate lack of information on technology lack of market information

Resistance against Change (OBSTresist)
Ease of Imitation (OBSTimit)

VARIABLES	DESCRIPTION
Firm Specific Variables	
SizeS	SizeS = 1 if the firm has less than 50 employees
SizeL	SizeL = 1 if the firm has more than 500 employees
Expint	Export intensity = Sales from Exports / total Sales
INFOint	Importance of Internal Information Sources of the firm for Innovation
INFOcomp	Importance of close Competitors as Information Sources of the firm for Innovation
INFOscience	Importance of scientific Information Sources
GOALcost	Importance of Cost-Efficiency Goal of the firm
GOALqual	Importance of Quality Improvement Goal of the firm
PROTtime	Importance of Lead Time on Competitors as a Protection Mechanism of the firm
PROTlegal	Importance of Legal Protection Mechanisms of the firm
PROTstrat	Importance of Strategic Protection Mechanisms of the firm
OBSTcost	Importance of Cost and Risk Obstacle for the firm
OBSTlack	Importance of Lack of Opportunities for Innovation as an Obstacle to innovation by the firm
OBSTneed	Importance of No Need for Innovation as an Obstacle to innovation by the firm
OBSTinfo	Importance of Lack of Information for Innovation as an Obstacle to innovation by the firm
OBSTresist	Importance of Resistance against change within the firm as an Obstacle to innovation by the firm
OBSTimit	Importance of ease of Imitation of Innovations as an Obstacle to innovation by the firm
Industry Specific Variables	
TWP	TWP = 1 if firm is in Textile, Wood or Paper Industry (typically the Low Tech industries) (NACE Codes: 17, 18, 19, 20, 21, 22)
Electrical	Electrical = 1 if firm is in Electrical Equipment Industry (NACE Codes: 30, 31, 32, 33)
Food	Food = 1 if firm is in Food Business (NACE Codes: 15, 16)
Chemical	Chemical = 1 if firm is in Chemical Sector (NACE Codes: 24, 25)
M&M	M&M = 1 if firm is in Metals and Manufacturing (NACE Codes: 26, 27, 28, 29, 34, 35)
C4	4-firm concentration ratio of the industry at NACE 2 level

Tables

Table 1: Information Sources for Innovation

Internal Information Sources	information within the company information within the group
External Information Sources	
• From other Firms	information from suppliers raw materials/components information from equipment suppliers information from customers information from close competitors
• Scientific Information	information from Universities information from Public Research Institutes information from Technical Institutes
• Freely Available Information	patent information specialized conferences, meetings, publications trade conferences, seminars

Table 2: Innovation Strategies

- **Make** (develop technology in-house)
- **Buy** (source technology externally)
  - Embodied in
    - Personnel
    - Other Firms (Take Over)
    - Equipment
  - Disembodied
    - Licensing
    - R&D Contracting
    - R&D Consulting
- **Cooperate**

Table 3: External Technology Sourcing

External Technology Source	**BUY** [a]	**MAKE and BUY** [a]
Licensing	18 (41%)	122 (43%)
R&D Contracts	7 (16%)	145 (51%)
Consulting Agencies	13 (30%)	94 (33%)
Take Over	10 (23%)	67 (24%)
Qualified Personnel	26 (60%)	164 (58%)
Total Firms	43 (100%)	283 (100%)

a: % do not sum to 100 because firms can use several external sources simultaneously.

Table 4: Innovation Strategy and Firm Size					
Size	**No Innovation**	**Innovation**	**Make**	**Buy**	**Make and Buy**
< 50 employees	203	117	32	28	48
50-250 employees	62	114	25	4	80
250-500 employees	21	95	12	6	66
> 500 employees	9	113	6	5	89
Total Firms	295	439	75	43	283

Table 5: Descriptive Statistics Total Sample

			Correlation Matrix								
Variable	**Mean**	**Standard Dev**	**SizeS**	**SizeL**	**Expint**	**OBSTcost**	**OBSTlack**	**OBSTneed**	**OBSTinfo**	**OBSTresist**	**OBSTimit**
SizeS	0.44	0.5	1.00								
SizeL	0.17	0.37	-0.39	1.00							
Expint	0.45	0.36	-0.51	0.32	1.00						
OBSTcost	0.36	0.22	-0.18	0.16	0.16	1.00					
OBSTlack	0.23	0.18	-0.12	0.067	0.10	0.68	1.00				
OBSTneed	0.22	0.20	-0.016	0.021	-0.03	0.54	0.56	1.00			
OBSTinfo	0.27	0.19	-0.11	0.08	0.11	0.78	0.70	0.52	1.00		
OBSTresist	0.21	0.21	-0.12	0.064	0.089	0.54	0.60	0.41	0.56	1.00	
OBSTimit	0.25	0.24	-0.12	0.07	0.082	0.58	0.56	0.55	0.52	0.40	1.00

Table 6: Descriptive Statistics Innovating Firms in Sample

			Correlation Matrix																
Variable	Mean	Std Dev	SizeS	SizeL	Expint	INFO int	INFO comp	INFO scien	GOAL cost	GOAL qual	PROT time	PROT legal	PROT strat	OBST cost	OBST lack	OBST need	OBST info	OBST resist	OBST imit
SizeS	0.25	0.44	1.00																
SizeL	0.26	0.44	-0.34	1.00															
Expint	0.57	0.33	-0.43	0.26	1.00														
INFOint	0.59	0.20	-0.32	0.24	0.19	1.00													
INFOcomp	0.51	0.24	-0.10	0.11	0.078	0.24	1.00												
INFOscience	0.27	0.19	-0.18	0.21	0.031	0.34	0.36	1.00											
GOALcost	0.57	0.17	-0.11	0.056	0.10	0.15	0.19	0.22	1.00										
GOALqual	0.66	0.19	-0.039	0.087	0.11	0.13	0.19	0.16	0.49	1.00									
PROTtime	0.69	0.25	-0.18	0.22	0.12	0.16	0.12	0.15	0.19	0.19	1.00								
PROTlegal	0.15	0.15	-0.18	0.22	0.12	0.13	0.023	0.19	0.10	0.11	0.26	1.00							
PROTstrat	0.50	0.26	-0.16	0.14	0.19	0.20	0.17	0.19	0.23	0.17	0.43	0.31	1.00						
OBSTcost	0.43	0.17	-0.06	0.13	0.045	0.15	0.22	0.18	0.16	0.18	0.20	0.19	0.24	1.00					
OBSTlack	0.27	0.16	-0.072	0.012	0.033	0.13	0.21	0.24	0.043	0.070	0.08	0.09	0.15	0.59	1.00				
OBSTneed	0.22	0.18	-0.065	0.068	-0.025	0.085	0.051	0.13	0.078	0.095	0.09	0.057	0.059	0.54	0.50	1.00			
OBSTinfo	0.32	0.16	-0.025	0.014	0.026	0.087	0.14	0.16	0.12	0.11	0.13	0.096	0.15	0.66	0.61	0.48	1.00		
OBSTresist	0.24	0.19	-0.12	0.071	0.092	0.14	0.17	0.16	0.011	0.078	-0.02	0.051	0.087	0.35	0.47	0.33	0.37	1.00	
OBSTimit	0.30	0.23	-0.051	0.059	-0.047	0.042	0.051	0.028	0.069	0.085	-0.08	0.014	-0.024	0.47	0.41	0.51	0.32	0.28	1.00

Table 7
Firm's Decision to Innovate (1) or Not (0)

Number of observations	734
Log likelihood function	-338.07
Restricted log likelihood	-494.55
Chi-squared	312.96***

Variable	Coefficients	Standard Error
Constant	-0.366***	0.0997
SIZES	-0.205***	0.0486
SIZEL	0.287***	0.0864
Expint	0.374***	0.069
OBSTcost	0.901***	0.177
OBSTlack	-0.0282	0.186
OBSTneed	-0.91***	0.156
OBSTinfo	0.395*	0.196
OBSTresist	-0.352**	0.139
OBSTimit	0.246*	0.123
Food	0.169†	0.0961
TWP	0.066	0.0873
Chemicals	0.247**	0.101
M&M	0.199*	0.0868
Electrical	0.383**	0.125

*** p < .001, ** p < .01, * p < .05, † p < .1.

Table 8: Marginal Effects for of Size

Variable	SizeS = 0	SizeS = 1	SizeL = 0	SizeL = 1
Expint	0.2112***	0.3684***	0.4145***	0.0704**
OBSTcost	0.508***	0.886***	0.997***	0.169**
OBSTlack	-0.0159	-0.0277	-0.312	-0.0053
OBSTneed	-0.513***	-0.895***	-1.007***	-0.171**
OBSTinfo	0.223*	0.389*	0.438*	0.0743†
OBSTresist	-0.199**	-0.346**	-0.39**	-0.662*
OBSTimit	0.139*	0.242*	0.273*	0.0463†
Food	0.0954†	0.166†	0.187†	0.0318
TWP	0.0372	0.0649	0.073	0.0124
Chemicals	0.14*	0.243**	0.2739**	0.0465*
M&M	0.112*	0.196*	0.2204*	0.0374†
Electrical	0.216**	0.377**	0.4244**	0.0721*

*** p < .001, ** p < .01, * p < .05, † p < .1.

Table 9: Decision to Source Technology Internal or External

Number of observations	363
Log likelihood function	-221.1
Restricted log likelihood	-287.13
Chi-squared	132.07***

Variables	MAKE	BUY	MAKE and BUY
Constant	0.0936	0.0794*	-0.173
	(0.146)	(0.0359)	(0.18)
SIZES	0.0717	0.0488***	-0.12*
	(0.0486)	(0.0136)	(0.0606)
SIZEL	-0.132†	-0.0183	0.151*
	(0.0701)	(0.0152)	(0.0701)
Expint	0.0849	-0.0305*	-0.0544
	(0.0658)	(0.0146)	(0.0764)
OBSTcost	-0.0149	-0.0966*	0.0817
	(0.16)	(0.0399)	(0.198)
OBSTlack	-0.0778	0.0623†	-0.0155
	(0.157)	(0.0368)	(0.192)
OBSTneed	-0.156	0.0466	0.109
	(0.143)	(0.0322)	(0.17)
OBSTresist	-0.0231	-0.0992***	0.0761
	(0.114)	(0.0301)	(0.142)
OBSTimit	0.166	-0.0291	-0.137
	(0.107)	(0.0228)	(0.122)
INFOcomp	-0.228*	0.079***	0.149
	(0.1)	(0.0203)	(0.102)
INFOint	-0.227†	-0.0273	0.255*
	(0.118)	(0.0256)	(0.127)
INFOscience	0.091	-0.0347	-0.0026
	(0.12)	(0.0277)	(0.147)
GOALqual	-0.115	-0.0223	0.138
	(0.117)	(0.027)	(0.141)
GOALcost	-0.088	-0.0527†	0.141
	(0.123)	(0.0299)	(0.15)
PROTlegal	-0.068	-0.089**	0.157
	(0.136)	(0.0348)	(0.168)
PROTstrat	-0.0397	-0.0173	0.057
	(0.083)	(0.0195)	(0.102)
PROTtime	0.049	-0.041*	-0.0082
	(0.085)	(0.0197)	(0.103)
Food	-0.056	-0.0318	-0.087
	(0.116)	(0.027)	(0.14)
TWP	0.0554	-0.0471†	-0.0083
	(0.106)	(0.025)	(0.129)
M&M	0.0961	-0.0258	-0.0703
	(0.106)	(0.0238)	(0.126)
Chemicals	0.0174	-0.0787**	0.0613
	(0.106)	(0.0274)	(0.133)
Electrical	0.0345	-0.0751**	0.0406
	(0.115)	(0.0285)	(0.142)

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .1$.
Standard Errors in brackets.
Probabilities at the mean vector are 0=0.144 1=0.033 2=0.823.

Table 10: Embodied or Disembodied External Technology Sourcing			
Number of observations			303
Log likelihood function			-294.65
Restricted log likelihood			-322.44
Chi-squared			55.59***
VARIABLE	**EMBODIED**	**DISEMBODIED**	**EMBODIED and DISEMBODIED**
Constant	0.097	-0.0935	-0.0037
	(0.07)	(0.14)	(0.21)
SIZES	0.135***	-0.0355	-0.10
	(0.037)	(0.066)	(0.10)
SIZEL	-0.16***	0.073	0.0867
	(0.049)	(0.082)	(0.12)
OBSTcost	0.122	-0.336*	0.213
	(0.08)	(0.16)	(0.244)
PROTlegal	-0.335**	0.258	0.077
	(0.115)	(0.21)	(0.317)
PROTstrat	0.122*	-0.292**	0.17
	(0.055)	(0.11)	(0.167)
Make	-0.0732†	0.208*	-0.135
	(0.042)	(0.057)	(0.13)
C4	-0.454***	0.351†	0.103
	(0.115)	(0.196)	(0.296)

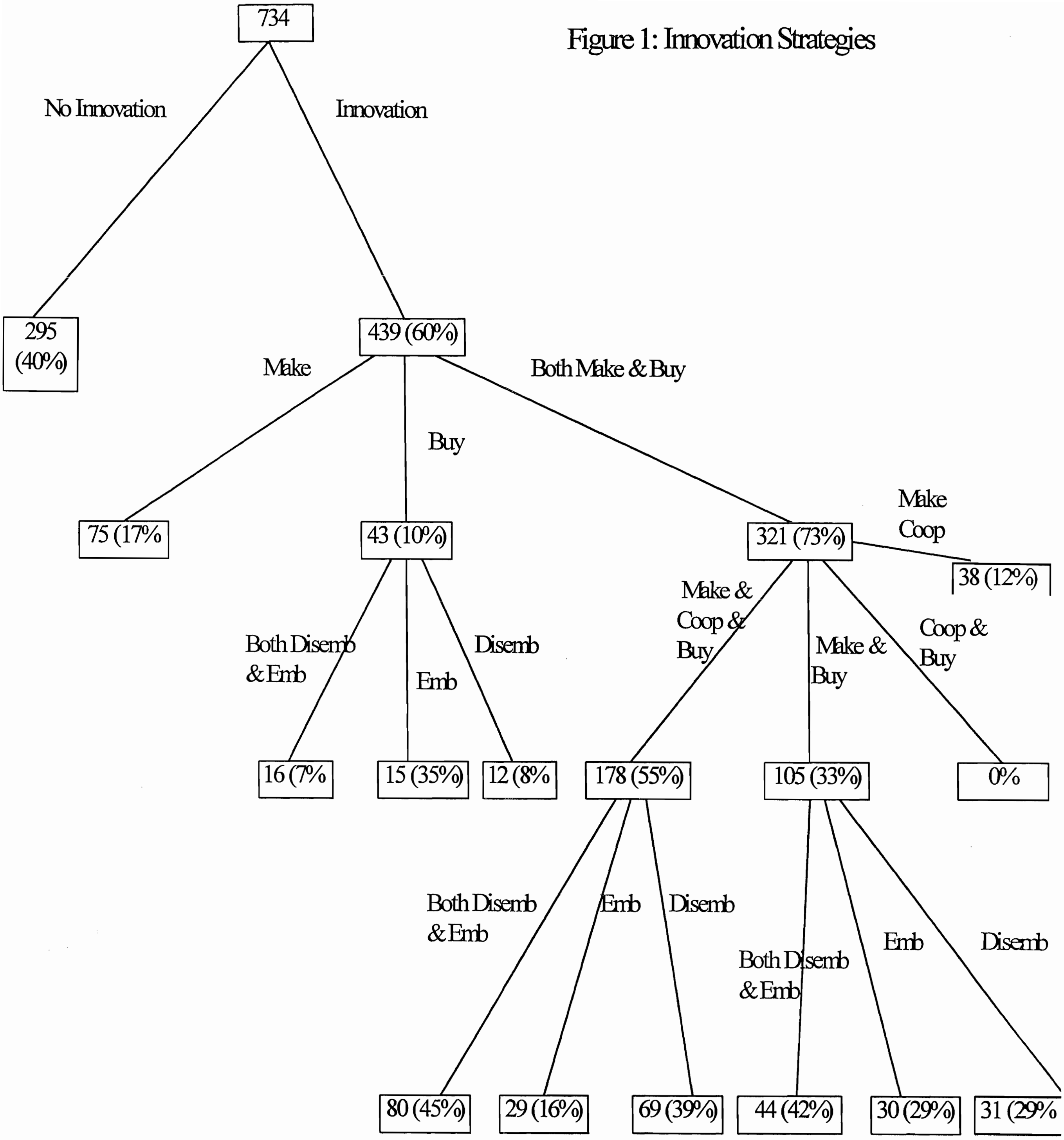
*** p < .001, ** p < .01, * p < .05, † p < .1.
Standard Errors are between brackets.
Probabilities at the mean vector are 0=0.181 1=0.359 2=0.461.

Table A1: Decision to Source Technology Internal or External, Best Fit

Number of observations			363
Log likelihood function			-221.1
Restricted log likelihood			-287.13
Chi-squared			132.07***
Variables	**MAKE**	**BUY**	**MAKE and BUY**
Constant	0.067	0.077*	-0.14
	(0.14)	(0.034)	(0.17)
SIZES	0.067	0.048***	-0.11†
	(0.047)	(0.013)	(0.059)
SIZEL	-0.14*	-0.017	0.16*
	(0.071)	(0.015)	(0.07)
Expint	0.069	-0.033*	-0.036
	(0.063)	(0.014)	(0.074)
OBSTcost	0.017	-0.094**	0.078
	(0.14)	(0.035)	(0.18)
OBSTlack	-0.05	0.056	-0.0055
	(0.15)	(0.036)	(0.19)
OBSTresist	0.01	-0.091**	0.08
	(0.11)	(0.029)	(0.14)
INFOcomp	-0.25**	0.079***	0.17†
	(0.098)	(0.019)	(0.097)
INFOint	-0.25*	-0.039	0.29*
	(0.12)	(0.026)	(0.12)
GOALcost	-0.13	-0.066*	0.2
	(0.11)	(0.028)	(0.13)
PROTlegal	-0.1	-0.088**	0.19
	(0.14)	(0.034)	(0.16)
PROTtime	0.24	-0.047**	0.023
	(0.08)	(0.019)	(0.098)
Food	-0.0058	-0.035	0.041
	(0.11)	(0.026)	(0.14)
TWP	0.079	-0.048†	-0.031
	(0.11)	(0.025)	(0.13)
M&M	0.12	-0.028	-0.087
	(0.11)	(0.024)	(0.13)
Chemicals	0.027	-0.08**	0.053
	(0.11)	(0.027)	(0.14)
Electrical	0.058	-0.081**	0.023
	(0.12)	(0.028)	(0.14)

*** p < .001, ** p < .01, * p < .05, † p < .1.
Standard Errors in brackets.
Probabilities at the mean vector are 0=0.148 1=0.034 2=0.819.

Figure 1: Innovation Strategies



Footnotes

[1] We would like to thank the IWT for generously providing us with the data for this research.

[2] However, Arora & Gambardella (1990) found larger bio-tech firms to be more active in external sourcing.

[3] Note that contrary to many studies in innovation, we can construct a direct output measure of innovation and need not proxy with R&D expenditures or patents.

[4] Identification of external sourcing is based only on the extent to which the strategies have been used or not. Information on budgets was incomplete and unreliable.

[5] The questionnaire explicitly described cooperation as an active participation of the firm in the project.

[6] The alternative models relate to which control variables to include, how to define and group the independent variables, whether to include interaction terms.

[7] Of the 320 small firms, only 22 are in the chemical sector and 12 in the electrical sector.

[8] Again due to missing values, the sample is reduced from 326 observation to 303.