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Exposing Strategic Assets to Create New Competencies: The Case of Technological Acquisition in the Waste Management Industry in Europe and North America

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This paper presents a model that complements the research stream of transaction cost economics with the dynamic capabilities approach. The paper shows that, even though technological alliances involving specific assets deployed in emerging industries are exposed to high transaction costs, they possess attributes that make them attractive. First, they facilitate the creation of tacit competencies, and second, they reduce the uncertainty arising from technological innovation and regulatory changes. The model is empirically tested in the hazardous waste management industry by using primary data collected through the use of questionnaires. The method links governance structure choices to managers' perceptions of the uncertainty surrounding the acquisition of technology.

1. *Introduction*

This paper investigates the fundamental drivers of the choice of alliance for acquiring new technological competencies in industries marked with high environmental uncertainty.

Transaction costs economics (TCE), developed by O. E. Williamson (1975, 1985), analyzes the comparative efficiency of governance structures in response to the level of uncertainty and specificity of the transaction. Vertical integration is the response to the inability of arm's-length market relationships to govern exchange efficiently for frequent transactions, entailing a high level of specialized assets and uncertainty associated with the exchange. Hybrid forms, like alliances, are located between market and hierarchy in

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terms of strength of their incentives, administrative controls and performance attributes. According to Williamson, TCE 'is concerned with the organization of transactions for mature goods and services and introduces parameter shifts once at a time. Added complications arise when innovation is introduced and when a series of parameter shifts occur together' (Williamson, 1991, p. 292). Williamson also states, 'added apparatus is needed to deal with the full set of issues that arise when responsiveness in real time, rather than equilibrium contracting is the central concern' (p. 293).

Indeed, TCE does not explain why many firms are engaging in hybrid forms, such as alliances for transactions involving idiosyncratic assets in competitive environments marked by rapid changes. Examples can be found in the biotechnology industry (Powell *et al.*, 1995) and the semiconductor industry (Shuen, 1994).

Several authors have pointed out the need to complement TCE with other approaches to analyze alliance strategies. Zajac and Olsen (1993) propose a transactional value framework for analyzing interorganizational strategies that address joint value maximization and the processes by which exchange partners create and claim value. Balakrishnan and Koza (1993) study how firms use a joint venture to gather more information about its value when there is a significant level of information asymmetry between the two parties. Doz and Shuen (1995) adopt a perspective rooted in organizational learning to complement the TCE model by focusing on the dynamic processes within partnership over time. Kogut (1991) and Chi and McGuire (1996) investigate how transaction cost and strategic option considerations interact to influence a firm's evaluation of collaborative venturing as a market entry mode for learning more about the partner for future expansion of the collaboration or acquisition of the partner's stake.

The dynamic capabilities approach to strategy (Langlois and Robertson, 1995; Teece *et al.*, 1997) offers a broader framework to analyze the choice of alliance to acquire new competencies in a dynamic environment. The approach proposes that the structure of capabilities in the economy affects the pattern of organizations in ways that are not fully explicable in terms of the transaction costs. This approach emphasizes the key role of strategic management in adapting, integrating and reconfiguring internal and external skills, resources and functional competencies toward changing environments. In this context, creating complex competencies rather than protecting specific assets is the main issue.

Building on these research streams, I propose a comprehensive treatment of organizational responses to uncertainties in the context of technological acquisition. I demonstrate that exposure to transaction costs is required to create and develop competencies in an environment marked by high technological and regulatory uncertainty. This paper shows that alliances are not just located between market and hierarchy, but are seen to provide the most flexible learning vehicle, and adequate, though incomplete, safeguards for strategic assets.

Most of the TCE empirical literature has compared contracting or hybrid forms to vertical integration. I hope to make a contribution by comparing alliance to vertical integration and contracts concurrently. Furthermore, I empirically show the complementarity of TCE and the dynamic capabilities approach.

The waste management industry is a very interesting example of an emerging industry marked by high environmental, technological and organizational uncertainty. In the early 1990s, this industry was still in its exploratory phase. Heavily dependent on regulation for the definition of its boundaries and market, it was rapidly building on competencies from various industries (i.e. chemical, biotechnology and nuclear).

In this industry, firms rely on several types of governance structures to acquire the technological knowledge necessary to manage waste. In a sample of 1690 technological acquisitions in Europe and North America, 705 were acquired through vertical integration (42%), 484 from alliance partnerships (29%) and 501 through contracts with unaffiliated firms (29%) (Delmas, 1996). The balanced distribution of governance structures in these three groups allows a good comparison between them.

Measuring intangible variables is the main difficulty with the empirical literature on TCE (Klein and Shelanski, 1995) as well as of the more recent dynamic capabilities approach. The approach chosen in this paper is to ask direct questions to the managers who are in charge of governance choices for technological acquisitions on the variables affecting their choices.

Section 2 is dedicated to the description of the model and the hypotheses. Section 3 explains the specificities of technological development activity in the hazardous waste management industry and identifies the variables which we hypothesize drive the choices of governance structures. Section 4 develops the empirical test. Finally, section 5 includes discussions on the results and concluding remarks.

2. *A Model of Governance Structure Choices to Acquire New Competencies*

The unit of analysis for studying choices of governance structure is the transaction, as suggested by Williamson (1985). For the purpose of this study, the class of transactions I will refer to is the acquisition of technology. Technology itself is defined here as a set of competencies. It is the practical knowledge, know-how, skills and artifacts that can be used to develop a product/service and/or a production/delivery system. It can be embodied in people, materials, cognitive and physical processes, plant, equipment and tools (Rosenbloom and Burgelman, 1989; Loveridge and Pitt, 1990).

There are many possible governance structures that could be employed from vertical integration to market in order to acquire technological competencies. The analysis is focused on three forms of governance structures: internal development, development by alliance and acquisition by contract.

At one extreme, the innovator can integrate into all of the necessary complementary assets. This means that he develops the technology inside the firm. This is commonly described as 'internal development.' This governance structure, through internal hierarchy and 'fiat mechanisms', reduces transaction costs to their minimum (Williamson, 1985). The innovator can also acquire another company. The incentives to use mergers and acquisitions for technological acquisition have been the object of comprehensive research (Granstrand and Sjolander, 1990; Laamanen and Autio, 1996). However, mergers and acquisitions are considered outside the scope of our study because they address questions relating to the merger of two organizations as a whole (Cartwright and Cooper, 1993), rather than the analysis of single transactions for technological acquisitions.

At the other extreme, the innovator can try to gain access to these assets through straightforward contractual relationships (component supply contracts, fabrication contracts, service contracts, license contracts, etc.). However, technology markets might have substantial information imperfections and transactions costs. The tasks of finding a technology provider, transferring the technology inwards, and applying it to commercially successful new products and processes could inhibit the use of contracts for technology acquisition (Lowe and Taylor, 1998).

Between the fully integrated and fully contractual extremes are many 'hybrid' modes of governance such as alliances or collaborative arrangements (Williamson, 1991). Alliances are defined in this study as 'interfirm co-operative arrangements, involving flows and linkages that utilize resources and/or governance structures from autonomous organizations, for the joint accomplishment of individual goals linked to the corporate mission of each sponsoring firm' (Parkhe, 1991, p. 581). They are relationships between firms which have legally separate identities, yet are economically interrelated (Sydow and Windeler, 1998). Alliances cover diverse relationships from technology and know-how exchanges, joint product development and cooperative research.

At one end there are joint ventures, which involve partners creating a new entity in which they share equity and which most closely replicate the hierarchical control features of organizations. At the other end there are alliances with no sharing of equity that have few hierarchical controls built into them. The common features of these collaborative arrangements are that the relationship is not fully determined by ownership or formal contract (Eccles and Crane, 1987). Since I am interested in knowing the conditions favoring the choice of alliances compared to contract or vertical integration, I will remain at an aggregate level of alliance definition.

In some instances, when compared to hierarchical relations, these relationships are more loosely coupled and stay market sensitive (i.e. remain subject to a 'market test') (MacMillan and Farmer, 1979). Alternatively, in bilateral contractual arrangements, such as technology sharing or joint development agreements, the technology is less tightly packaged than in the case of unilateral contracts where it is exchanged for cash payment.

An important difference between governance structures lies in their ability to adapt to changing circumstances. According to TCE, contracts are better suited to autonomous disturbances for which prices serve as sufficient statistics and where individual buyers and suppliers can reposition autonomously. Recourse to a different mechanism is suggested as the need for coordinated realignment increases in frequency and importance. The authority relation (fiat) has adaptive advantages over autonomy for transaction of a bilateral (or multilateral) kind. The advantage of hierarchy over contract in coordinated adaptation is not realized without costs. Hierarchy involves weaker incentive intensity and greater bureaucratic costs than contract.

Because the governance of an alliance is bilateral, the arrangement can be viewed structurally as between a market transaction and a hierarchical relationship. By combining some of the incentive structures of markets with the monitoring capabilities and administrative controls associated with hierarchy (internal organization), an alliance can provide a superior means to gain access to technological and other complex capabilities which require coordinated responses.

The first set of hypotheses, consistent with TCE, tests the superior ability of alliances to transfer complex and tacit technological competencies over contract modes. It also tests whether alliances formed to acquire new technologies are associated with higher transaction costs than vertical integration. These transaction costs are linked to search and bargaining costs as well as the exposure of the innovator to hazards and dependencies. The second set of hypotheses is drawn from the dynamic capability approach. It includes perspectives on access to complementary assets, organizational learning and risk reduction. It shows the superior ability of alliances to acquire new technologies over vertical integration in a changing environment. Finally, a strategic perspective is proposed to test how alliances provide a better mechanism than contract to develop strategic technologies. Each hypothesis compares alliance to either vertical integration or contract one at a time. This approach has been chosen to facilitate the understanding of the impact of each variable. There is therefore no hypothesis for which alliance is superior to contract and vertical integration. The advantage of alliance over these two other governance structures derives from the combination of the different hypotheses.

2.1 Transaction Cost Economics

Pavitt (1987, p. 185) has characterized most technology as being specific, complex, often tacit and cumulative in its development. According to TCE, this increases the need for organizational linkages and the development of transactional difficulties.

Tacit and Complex Competencies Rosenberg provides a good working definition of tacit knowledge: 'the knowledge of techniques, methods and designs that work in certain ways and with certain consequences, even when one cannot explain exactly why' (Rosenberg, 1982, p. 143). This heuristic, subjective and internalized knowledge is not easy to communicate and is better learned through example and practice. By contrast, articulated knowledge can be transmitted in formal systematic language. When knowledge is tacit, it cannot be effectively transferred in codified form; its exchange must rely on intimate human contact (Collins, 1974; Teece, 1977). It is difficult to draft simple contracts governing the sale or licensing of such capabilities (Mowery, 1983, Pisano, 1990). Alliances possess the necessary organizational linkages to leverage technologies inside the firm as well as complement them by learning from the partner (Kogut, 1988; Prahalad and Hamel, 1990; Doz and Hamel, 1995). Alliances allow the exchange of tacit or routine embodied knowledge (Harianto and Pennings, 1990; Fruin, 1992). The predicted effect of tacitness can be formalized as:

H1 *The more tacit the technology, the more likely the technology will be developed through alliance rather than acquired through a contract.*

Complexity arises when components of an applied system have multiple interactions and constitute a non-decomposable whole (Singh, 1997).[1] Even if it is possible to identify physical or logical subsystems, it is not possible to decompose complex technologies into these subsystems while maintaining the technology at or close to optimum performance level.

Complexity raises the difficulty of writing contracts that include all specifications and interdependencies. The characteristics of complex technologies make market trading for them or for their significant components subject to exchange difficulties, rendering the market inefficient. Market exchange will not allow close enough coupling to provide an efficient and closely coordinated interface between organizations, and it interrupts information exchange and other interdependent activities. This hinders the close configuration of components (Camacho and Persky, 1988; Teece, 1992).

Technological complexity is often identified as an important motive for interorganizational cooperation (Dodgson, 1992; Rycroft and Kash, 1994). Osborn *et al.* (1990) show that alliances provide the multiple linkages considered important in a high-technology context. Bailetti and Callahan (1993) explore the coordination structure of international collaborative technology arrangements. According to them, management of this arrangement requires the creation and maintenance of a wide variety of strategic and operational interdependencies within and between companies. The predicted effect of complexity can be formalized as:

H2 The more complex the technology, the more likely the technology will be developed through alliance rather than acquired through a contract.

Transaction Costs Williamson (1985) identifies site, physical, and human asset specificity as distinct types of transaction-specific investment. Transaction costs increase when asset specificity increases due to opportunism (Williamson, 1985). Transaction costs can be decomposed into four separate costs related to transaction: (i) search costs, (ii) contracting costs, (iii) monitoring costs and (iv) enforcement costs (Williamson, 1985; Hennart, 1993). Search costs refer to the costs associated with finding a partner. Contracting costs relate to the monitoring and writing of the agreement. Monitoring costs refer to the costs associated with monitoring the agreement to ensure that

[1] According to Miller *et al.* (1995, p. 368): 'complex product systems embody at least three general characteristics: first they are made up of many interconnected, often customized elements (including control units, subsystems and components), usually organized in a hierarchical way, second CSs exhibit non-linear and continuously emerging properties, whereby small changes in one part of the system can lead to large alterations in other parts of the system, and third there is a high degree of user involvement in the innovation process, through which the needs of the economic environment feed directly into the innovation process.'

each party fulfils the predetermined set of obligations. Enforcement costs refer to the costs associated with *ex post* bargaining and sanctioning a trading partner that does not perform according to the agreement.

Alliances for the acquisition of new technology involve a high level of specialized investment, especially in terms of soft managerial time, and might be associated with higher transaction costs than vertical integration (Williamson, 1991). Alliances fundamentally possess the shared feature of ongoing mutual interdependence, a condition in which one party is vulnerable to another whose behavior is not under the control of the first. Many authors have discussed the high search and bargaining costs, and the *ex post* internal governance costs associated with alliances (Brockhoff, 1992; Gray and Yan, 1992; Hill and Hellriegel, 1994).

Alliances are inherently incomplete contracts because the partners cannot anticipate all future contingencies at the time the contracts are written. Such arrangements therefore expose each firm to opportunistic exploitation by its partner (Williamson and Ouchi, 1981) that could lead to renegotiations and unequal sharing of gains, a situation commonly known as the hold-up problem (Hart and Moore, 1990; Hart, 1995). The risks of *ex post* opportunism in an alliance is high because to promote organizational learning alliances need to combine the embedded organizational systems of the parties. Shared systems are necessary to provide the alliance with the opportunity to exploit routines and other embedded knowledge. Therefore, through alliances, a firm exposes its organizational resources and core competencies to transmission (leakage) to a partner (Hamel, 1991). The predicted effect of transaction costs associated with alliances can be formalized as:

H3 *Technological acquisition through alliance is associated with a higher level of transaction costs than vertical integration.*

Asset specificity, alone, does not explain the use of alliance, especially when innovation is at issue. The main focus of TCE has been manufactured products for which a market exists. Additional issues arise when the market does not exist and where there is a need to find innovative solutions. The following hypotheses, taken from the dynamic capability approach, stress the need for linkages to other technologies and access to complementary assets for the successful development of innovative solutions.

2.2 Access to Complementary Assets

Innovation is a quest into the unknown. It involves searching, probing and reprobing technological opportunities. Innovation is characterized by technological interrelatedness between various subsystems. Because R&D returns are subject to enormous uncertainty, it is hazardous, if not impossible, to determine the price for a product that has yet to be created.

The decision to form an alliance as compared to a contract is not simply based on transfer costs and lock-in problems. It is also influenced by the availability of the technology and the expected experiential knowledge accumulation that will be the basis for future development of the firm. Alliance provides advantages over vertical integration to gain access to complementary technologies.

Linkages to other technologies, complementary assets and to users must be established if innovation is to be successful. In a regime of rapid technological development, competencies are so well distributed among the different partners that no single firm has all the internal capabilities necessary for success (Powell, 1990). Collaborative arrangements to exploit technological innovation may be based around exploitation of complementary assets supplied by the respective parent firms (Teece, 1986, 1989). As firms might lack competence in a number of technological fields, cooperation with other enterprises creates the necessary complementary technology inputs, enabling these companies to capitalize on economies of scope through joint efforts. Alliances provide firms with a unique opportunity to leverage their strengths with the help of partners since a wide range of interorganizational linkages is critical to knowledge diffusion, learning and technology development (Powell, 1998). In bringing together firms with different skills and knowledge bases, alliances create unique learning opportunities for the partner firms (Doz, 1996; Inkpen, 1998). Hagedoorn (1993) found that technological complementarity was one of the most mentioned motives for strategic alliances. The predicted effect of the firm's need to access complementary technological competencies can be formalized as:

H4 The more the need for complementary technological competencies, the more likely the technology will be developed through alliance rather than internally.

In conclusion, alliances facilitate the acquisition of complementarily complex and tacit competencies. The specificity of an emerging industry is its high level of environmental uncertainty. Not only are the competencies dispersed among different organizations, but firms must also face a high uncertainty concerning the evolution of the technology and the industry in terms of demand and standards. In this context, the ability to adapt quickly to changing circumstances is key to gaining a competitive advantage.

2.3 Strategic Behavior in Changing Environments

Highly integrated organizations can be somewhat insulated from the environment and, hence, slow to react. Nelson and Winter (1982) demonstrate how organizational routines can be an obstacle to change. The firm choosing an integrated governance structure in an uncertain environment may find it difficult to manage and relatively difficult to dissolve. Pavitt (1987) and Mowery (1983) have shown how large companies resist innovation. Organization theorists (Lawrence and Lorsch, 1967; Pfeffer and Salancik, 1978) have argued that loose (i.e. less vertically integrated) structures are more effective under conditions of high environmental uncertainty. Alliance allows firms to react promptly to external stimuli, while at the same time reducing internal investments, thus minimizing the risk of sunk costs should the need arise for strategic readjustment.

Technological Uncertainty Technological uncertainty refers to the probability of an improvement in technology, (i.e. new generations of technology) which might render obsolete the current technological effort (Robertson and Gatignon, 1998). A high level of technological uncertainty has been attributed to certain stages of the lifecycle of technology (Brockhoff, 1992). In particular, emerging technologies are marked by important uncertainty concerning their potential success and value (Dosi, 1982). Many studies refer to the reduction of risk in R&D as a major motivation to share activities (Hladik and Linden, 1989). Hagedoorn (1993) suggests that technological alliances can be a way of monitoring the evolution of technologies in order to assess technological synergies, near-future results of general scientific knowledge and relevant complementary technologies.

Various authors in the economics of technological change literature have captured the idea that the beginning of the evolution of a technology is characterized by a multiplicity of potential approaches (Utterback and Suarez, 1993). Technological change can result in a competitive struggle between new and incumbent firms in an industry (Schumpeter, 1942; Abernathy and Clark, 1985; Tushman and Anderson, 1986).

When the level of competition between technological designs is high, firms cannot develop all potential possibilities internally. Firms can use pre-competitive partnership to enlarge their technology portfolio through the formation of alliances with competitors, thereby reducing the initial cost of large early-stage research projects. Such alliances allow pooling of resources in order to scan the technology horizon on a much broader scale than would be the case with internal development (Devlin and Bleackley, 1988). Kogut

(1991) explores the perspective that joint ventures are created as 'real options' to expand in response to future technological and market developments. In this sense, developing capabilities through alliances is an investment in opportunity. Without making the initial stake, the firm would be unable to act to its advantage when opportunity does strike. The predicted effect of technological uncertainty can be summarized as:

H5 The more the technological uncertainty, the more likely the technology will be developed through alliance rather than developed internally.

Regulatory Uncertainty In the context of an emerging industry, the institutional environment—comprising the rules of the game—can be an additional source of uncertainty for organizations. The ability of the institutional environment to credibly commit and favor private investment (Levy and Spiller, 1994) is one component of regulatory uncertainty. The institutional environment can also create uncertainty by changing the regime of appropriability (property rights) that governs the innovator's ability to garner the profits generated by an innovation (Teece, 1986). More specifically, in the context of an emerging industry, regulators might operate by experimentation. This can create an important source of uncertainty for firms. Very few studies have analyzed governance structure choices in conditions of regulatory uncertainty (Walker and Weber, 1984; Combier, 1994). Most of the work has been confined to the international business literature, which explains the use of international alliances by the desire of firms to share the ownership of their foreign subsidiaries with local firms in order to reduce uncertainties arising from a hostile regulatory environment (Ring *et al.*, 1990). It is only very recently that scholars have begun looking at the interaction between environmental regulations and firm strategies (Wallace, 1995; Rugman and Verbeke, 1998). They show how this type of regulation is perceived as a major source of uncertainty for managers.

Concerning technological development, alliances can help firms to produce standards and agree on new designs. For the market for technologies to expand, firms need their innovations to be accepted by both the user and the regulator. When radical innovations are proposed, by combining the effort of several companies, alliances can help to set standards, thereby reducing uncertainty, and enabling the market to grow and allow learning among suppliers and users (Grindley, 1995). Without agreements on standards, the market might not develop at all. Users might not be able to benefit from technological advances, while suppliers might find regulations confusing.

Therefore, the predicted effect of the uncertainty concerning the paradigm or standard can be formalized as:

H6 *The greater the regulatory uncertainty, the more likely the technology will be developed through alliance rather than developed internally.*

Strategic Technologies Decisions to expand the technological boundaries of the firm will be more likely when the technology is viewed as strategically important (Pisano, 1990). Alliances are increasingly viewed as strategic weapons for competing within critical multi-domestic or global arenas (Harrigan, 1988; Perlmutter and Heenan, 1986; Kotabe and Swan, 1995). Most alliances have been formed between existing or potential competitors, and have involved products or markets which constitute the primary or 'core' activities of the parent firms (Hergert and Morris, 1988; Geringer and Woodcock, 1989). As has been discussed previously, contracts cannot provide the knowledge that is necessary to develop new competencies. Alternatively, alliances incur high transaction costs, and therefore managers will use alliances only for strategic technologies that might procure a competitive advantage for their firm. Thus, a high level of strategic importance should be negatively linked to contracts compared to alliances. The predicted effect of the strategic importance of the technology can be formalized as:

H7 *The more strategic the technology, the more likely it will be developed through alliance rather than acquired through contract.*

Hence, by using alliances, firms expose their assets to transaction costs in order to access complementary competencies for the creation of new, complex and tacit competencies. An alliance provides the firm with the necessary ability to react to uncertainty arising from innovation and regulatory changes. In such conditions, rather than focusing on minimizing transaction costs, firms focus on building a competitive advantage. Table 1 reports the set of hypotheses and their expected signs.

3. *The Waste Management Industry*

Still in its emerging phase in the early 1990s, the waste management industry has been marked by uncertainties regarding environmental regulations, as well as the supply and demand for new technologies. Technological innovation can threaten hazardous waste management service companies with the entry of new competitors. It can also be a source of opportunity for firms

TABLE 1. Expected Signs of Hypotheses

Expected sign for	Alliance compared to contract	Alliance compared to vertical integration
Transaction cost economics		
H1 (complexity and tacitness)	+	=
H2 (complexity and tacitness)	+	=
H3 (transaction costs)	=	+
Dynamic capability		
Innovation in know-how		
H4 (complementary competencies)	=	+
H5 (technological uncertainty)	=	+
H6 (regulatory uncertainty)	=	+
H7 (competitive advantage)	+	=

=, significant difference; +, positive coefficient; –, negative coefficient.

to be ahead of legislation and to set future standards. In this industry—marked by unclear frontiers, high uncertainty and lack of information—firms must take strategic decisions on how to develop tacit and complex technologies (Sanchez, 1997). In such a context, access to complementary assets as well as flexibility is necessary to gain a competitive advantage.

The waste management industry may be described as including firms supplying pollution control, reduction, clean-up and waste-handling equipment, and related services (European Commission, 1994). This section aims at illustrating the hypotheses of our model and providing examples of alliances in this industry.

The development of the waste management industry dates from the mid-1980s with environmental regulations setting the broad framework for demand for environmental goods and services. Since this period, it has encountered important changes in terms of competencies and growth. At the beginning of the 1980s waste management was mainly a service-based industry with a low level of technological skills. Managing waste involved a single transfer of waste from its industrial source to a controlled landfill (in the better case). Fifteen years later, this industry has become highly technologically oriented with sophisticated treatments often mandated by new laws.

At the core of the industry is a group of identifiable technologies, which are used to clean-up existing processes and production ('end-of-pipe' equipment and/or technologies, e.g. waste incineration, vitrification and chemical neutralization). There is also a set of waste management and recycling technologies to recover waste for reuse and deal with past environmental damage, as well as a growing range of environmental services such as research, design and service activities. More than three-quarters of industry output is made up of end-of-pipe pollution abatement equipment. The rest includes general environmental services largely based on engineering and consultancy (European Commission, 1994).

In 1991, hazardous waste service management annual revenue reached $4 b. in Europe and $16 b. in the United States (Sheridan, 1994; Lorenz, 1995). The structure of the environment industry is highly dichotomized with a small number of large players accounting for more than half of the market alongside a very large number of small firms. Waste Management Inc. dominates the world market of waste management from the United States (with an annual revenue of $3.2 b. in 1990). Edelhoff and Hoechst in Germany led European waste equipment companies with an estimated environmental annual revenue of $700 m. in 1990 (European Commission, 1994).

The waste management industry is a heterogeneous industry with ill-defined frontiers on which information is scarce. It is very diversified with a variety of industrial products and services which have not been statistically classified, and for which current data is limited (OECD, 1992). The design of waste treatment technologies consists of developing technologies and/or systems of technologies to meet the current regulatory standards, and designing solutions for existing facilities to meet emerging, but as yet, unwritten standards. This section will describe the main uncertainties faced by waste management companies and the governance structures they use to acquire waste treatment technologies.

3.1 Regulatory Uncertainty

The main peculiarity of the market for hazardous waste management is its high dependence on regulation. Environmental regulations are laws designed to control conventional pollutants such as water, air and noise pollution, and toxic pollutants such as solid waste, pesticides and hazardous waste (Yandle, 1989). Henriques and Sadorsky (1996) found that government regulation does represent the single most important source of pressure on firms to consider environmental issues. Environmental regulations are compulsory and set the demand for waste management technologies. Waste management has been one of the key environmental issues since the 1980s following growing public concern about hazardous waste.[2] However, development of new waste management technologies can be discouraged by regulatory uncertainty

[2] At European Union level, more than 200 legal acts have been adopted in the field of the environment since 1973.

because of the timing, complexity of regulatory measures, and the extent and efficiency of their enforcement.

Environmental regulation is often separated into two major types. The most common, called command and control legislation, involves the setting of technology-based standards and emission levels based on existing methods of control. All affected firms are then required to comply in a manner that is similar to the best performing firms (Bonifant *et al.*, 1995). The second type, often dubbed the flexible or collaborative approach, relies less on technology identification and more on market mechanisms to solve environmental problems. Although market-based strategies to reduce pollution are under discussion, their use is still very limited.

Environmental regulation can also be differentiated based on whether it requires changes in manufacturing processes or changes in product design. Process-oriented regulations encourage companies to re-engineer their production technologies. Product regulations drive companies to create valuable new products that are less polluting or more resource efficient (Porter, 1991).

The process of regulation in the environmental field is highly political. Environmental problems are a sensitive issue subject to many different perceptions and values. As such, the prioritization of what is to be regulated does not always reflect what sound science and economic analysis would suggest. The regulator faces a multitude of sometimes-conflicting demands in a framework of imperfect information and data. A problematic issue about regulation is timing. If adequate phase-in periods that account for industry's investment cycles are not included, then industry can suffer significant short-term adjustment shocks. Furthermore, the lack of harmonization between different regulations might result in inefficiencies and, therefore, unnecessary costs for the industry.

In brief, environmental regulation, as it is currently conceived and implemented, often represents a source of considerable uncertainty for business managers. The process of environmental regulation is perceived by many companies as being complex and unpredictable (Birnbaum, 1984).

3.2 Environmental Regulation and Innovation

The reinforcement and extension of pollution abatement regulatory norms often reach the limits of existing technologies. As toxic wastes become more and more ineluctable (no recycling solution can be found), they require more sophisticated treatments.[3] This is why, since the late 1980s, the rate of technological innovation has been very high in this industry, and the simple

[3] Examples are the recycling of mercury, copper, nickel or chromium.

improvement of existing processes has been replaced by real innovations. It has been estimated that 50% of the environmental technology that will be employed in the next 15 years does not currently exist (OECD, 1996).

There are arguments that the relationship between environmental regulation and innovation is positive (Hawken, 1993; Wallace, 1995). For example, regulation can create entrepreneurial opportunities in the manufacturing of equipment needed to satisfy regulatory provisions. Porter and van der Linde (1995) maintain that regulations that focus on process changes often result in entirely new production technologies, and strict product regulations encourage companies to develop new products that are less polluting, use resources more efficiently and carry a higher perceived value. Environmental regulation may appear to disrupt and threaten a firm, but like other types of shocks, it can be conducive to change and innovation (Jacobs, 1992; Sharma and Vredenburg, 1998).

3.3 Dispersed Tacit and Complex Technological Competencies

Since regulation conditions the demand and the technological skills required in this market, and because of the lack of regulation harmonization between countries, national peculiarities remain in terms of competencies and level of development of the industry.[4] This poses additional complexity for the development of the waste management industry at the international level (Vogel, 1996). Furthermore, the technological competencies necessary for waste management companies to innovate are usually tacit, complex and dispersed among different types of industries and firms.

Waste management companies may be requested to find not-so-obvious solutions to the complex puzzles they have inherited. Managing waste in an economic, as well as an ecological, way requires global treatment solutions and coordination of different stages of the waste treatment process. In order to attain the best standards of treatment, waste management companies need to take an integrated approach that considers both pollution prevention and end-of-pipe treatment (e.g. the upstream changes that one might make in preventing pollution may affect the composition of the ultimate effluent).

The technological capabilities are not only in the hands of the waste management companies. The users or waste producers (engineering companies or equipment manufacturers) possess some of the technological skills

[4] However, if historically in Europe national legislation has been more significant in shaping the character and development of national markets, this balance is now shifting to a more integrated policy. Indeed, EC policy, in the form of Directives and Regulations, is having an ever-increasing impact at a national level.

necessary for developing treatment processes. Therefore, technological development in this particular sector is highly complex because many scientific disciplines and different parties have to be taken into account, highlighting the importance of coordination.

Developing technologies in this sector entails a great deal of specificity since the technology is usually customized for a specific waste processing plant. The tacit component of waste treatment technologies is also important since firms are implementing a new know-how for each different solution that cannot be codified.

Most waste management treatment technologies derive from technologies developed in other industries and are adapted for the specific purpose of treating waste. For example, technologies can come from the cement industry (cement kiln), biotechnology (anaerobic treatment), the chemical industry (methanization, electrochlorination, etc.) and the nuclear industry (polymer encapsulation).[5] In addition, each treatment technology combines several technological disciplines: hydraulics, chemistry, biotechnology, microelectronics, etc.

It is through technological competencies and innovation that companies from other sectors diversified into the waste management industry, and therefore compete with hazardous waste management companies (e.g. many chemical firms commercialized technologies that they had first developed for their own use).

3.4 A High Pace of Innovation

Innovation can allow firms to shift from a passive approach dictated by legislation to a more proactive assessment of the problem, sometimes preceding legislation. A considerable change in the structure of the environmental industry is taking place with a shift from end-of-pipe equipment and clean-up services to integrated, 'clean' environmental technologies. In the long term, this substitution may radically affect the structure of the environmental industry by increasing the importance of research, design, consulting and other services relative to clean-up and remediation goods and services.

Environmental technology solutions allow companies to be ahead of environmental regulations and establish a firmer grasp of environmental and

[5] As an illustration, recent breakthroughs in polymer chemistry have given new life to 20 year old filtration technologies, increasing their effectiveness in wastewater treatment. The result is a variety of highly inert and chemically resistant membranes, Teflon-like materials that contain microscopic pores with an average diameter of 0.005 microns. Another example is reverse osmosis, commonly used in desalinization, which employs a sensitive membrane capable of removing material in suspension (Harris, 1992).

product liabilities. They may allow industry to pre-empt some regulations. They also allow some leading companies to shape environmental regulations consistent with their own internal policies. These companies stand to gain a competitive advantage over their rivals (Shrivastava, 1995). The next paragraphs depict examples of alliances that have been used to acquire such complementary assets and flexibility in the waste management industry.

3.5 Examples of Alliances

Alliances in the waste management industry combine many types of participants, representing the variety of competencies and personnel that have to be combined to create new competencies in this industry. Competencies can originate from suppliers, distributors, competitors or from firms in other industries.

Alliances can occur between waste management companies and the waste producers. In this case, the users (waste producers) play an active part in design and development. These alliances combine competencies (knowledge of the waste and its process) from waste producers and waste management companies. For example, in 1994, Scott Paper Company and Laidlaw Environmental Services (the second-largest hazardous waste disposal company in North America) developed the first closed-loop system for disposal of wiping material that is contaminated with hazardous waste (Witt, 1994).

Alliances can also be built between waste management producers or between waste management companies, which are used as a way of widening the portfolio of technologies of these companies. For example, The Institute of Scrap Recycling Industries (ISRI) has signed a cooperative research agreement with the US auto industry's Vehicle Recycling Partnership (VRP). The scrap processors and automakers have agreed to work together on research to develop technology to recycle more parts of automobiles. The VRP is a research consortium of General Motors, Ford and Chrysler (*Iron Age New Steel*, 1994).

Alliances in the waste management industry can also aim at adapting competencies from other sectors or scientific disciplines. These alliances can occur between equipment manufacturers, engineering companies and waste management companies. For example, Custom Cryogenic Grinding Corporation (CCGC) and STI-K Polymer America, Inc. established a new facility to devulcanize rubber factory waste. The partnership combines STI-K's new technology to devulcanize rubber using its patented 'De-Link' process and CCGC's grinding and processing capabilities (Falconer, 1995).

Alliances can also combine a mix of broader competencies. With these alliances, firms can attempt to develop standard protocols. The designs can be negotiated *ex ante* between the main innovation agents, with an innovation structure designed to cope with uncertainty and risk.

Probably the most visible, and broadest, technical partnership to date in the United States is in California at the sprawling McClellan air base. There, AT&T, Du Pont and Monsanto are giving financial support to McClellan's Environmental Process Improvement Center in return for crucial cost performance data. In this instance, Clean Site Inc. acts as a nonprofit liaison which in turn is supported by the Environmental Protection Agency (EPA)'s Technology Innovation Office and Office of Research and Development (*Environment Today*, 1993).

In conclusion, in the waste management industry, competitive circumstances demand a range of new skills that far exceed the capabilities of existing organizations. Waste management companies use alliances to access different types of competencies in a very uncertain environment marked by regulatory changes and a high rate of innovation.

4. *Empirical Test*

Through questionnaires, 927 cases of technological acquisitions by companies in Europe and North America that manage hazardous waste were reported. Scales measuring the explanatory variables were constructed based on the perceptions of the technical directors in charge of technological development. On a total of 927 answers, 404 are for vertical integration (44%), 289 for alliance (31%) and 234 for contract (25%). The effect of the explanatory variables on the mode of technological acquisition is tested by specifying a multinomial logit regression.

The first questionnaire was mailed to the technical directors of 100 waste management companies in Europe, and 200 waste management companies in North America. The list and addresses have been taken from Frost and Sullivan (1992), Eurostaf Report (1991) and US databases. The questionnaire (the validity of which I tested with experts in the sector) listed 84 technologies and requested the technical directors to choose the ones that had been acquired by their companies. They had to cross the column corresponding to the organizational form chosen by their company. The three choices were 'internal development', 'alliance' and 'standard contract'. The technologies were chosen through existing reports (European Commission, 1990; Bipe Conseil Report, 1991; Frost and Sullivan, 1991). Then, a second questionnaire was sent to the responding companies, including only the technologies they had acquired, with questions on the attributes of each technology. On average, 23 cases of technological acquisition were obtained per company.

4.1 Operationalization and Measures

The dependent variable is the governance structure (GOV). Its values correspond to vertical integration, alliance or contract. Vertical integration means the development of the technology inside the company. Alliance is the development of the technology in partnership with another company. Contract means the acquisition of a technology that has already been developed (e.g. licensing, engineering contracting).

Uncertainty can be measured 'objectively' or 'subjectively'. Snow (1972) has empirically tried to relate real and perceived uncertainty. Knight (1921) suggested that we perceive the world before we react to it, and that we react to what we infer about perception. Thomson (1967) also suggested that judgments about uncertainties are bound to be significantly influenced by the perceptions and beliefs of the administration. Child (1972) indicated that perceptions guide the strategic choices that managers make in responding to their environment. Perceived uncertainty has been studied by Duncan (1972) and Snow (1972), but seldom, if ever, in relation to organizational strategy.

The waste management industry as described earlier is marked by a high level of uncertainty concerning its evolution, the technologies at stake and the behavior of firms. Consequently, I measured independent variables from direct questions to the technical directors in charge of technology development in the waste management companies. Our independent variables are therefore based on perceptions.

A *complex* technology was defined by the number of customized, interconnected components and the amount of feedback between them. Inspired by Caves and Bradburg (1988) and Masten *et al.* (1991), I measured *complexity* with a five-point scale from 'simple' to 'complex' (COMPX). Work on tacit knowledge has illustrated the difficulty with measuring this concept (Myers and Davids, 1992). *Tacitness* proved to be hard for the technical directors to understand. Following Kogut and Zander (1993), I replaced this notion with the concept of formalization and codifiability of the technology and its know-how content. In the questionnaire, a text explained these notions in detail with examples. It was stated that formalized technologies can be transferred through manuals describing the requisite procedures. On the contrary, informal know-how can only be transferred with the transfer of personnel or with interactions between teacher and student. The five-point scale was from 'formalized technology' to 'know-how' (TACIT).

TABLE 2. Independent Variable Definitions and Descriptive Statistics

Variable	Mean	Ecart type	Variance	Min	Max	*N*	Label
TACIT	0.5	0.32	0.1	0	1	721	degree of tacitness of the technology from formalized to tacit
COMPX	0.49	0.3	0.09	0	1	722	degree of complexity of the technology from simple to complex
LIFEC	0.45	0.24	0.06	0	1	724	development stage of the technology: decline, maturity, industrial development, development, research
COMPT	0.55	0.32	0.1	0	1	719	degree of competition of the technology with other technologies to process the same waste from not competing to competing
REGUL	0.48	0.37	0.14	0	1	638	degree of probability of updating the technology because of new regulatory constraints from low to high
COMP	0.61	0.37	0.14	0	1	691	degree of competencies of the firm in that technology from many competencies to need for external competencies
SHIFT	0.39	0.35	0.12	0	1	525	difficulty of shifting to another supplier from easy to very difficult
NREDEP	0.54	0.32	0.1	0	1	485	degree of non-redeployability of the technology
STRAT	0.48	0.34	0.12	0	1	676	degree of strategic importance of the technology
GGD	0.57	0.49	0.24	0	1	1690	waste management company
TURN	0.48	0.35	0.12	0	1	1164	annual revenue
INTER	0.45	0.46	0.31	0	1	1690	level of internationalization

Values are Pearson correlation,significance (two–tailed) and number+ of cases.

Transaction costs prove to be very problematic to operationalize. Two distinct measures were used to assess the *transaction difficulty* and the *redeployability of specific investments*. The first of these measures is an approximation of the difficulty of changing partners. The technical directors were asked, 'After 25% of the contractual agreement period has occurred, if major problems with your technology supplier occurs, how difficult would it be to shift to another supplier?' The five-point scale was from 'easy' to 'very difficult to shift' (SHIFT). For the second measure, concerning redeployability, the question was whether a specific investment made for developing the technology could be redeployed for other uses on a five-point scale from 'redeployable' to 'not redeployable' (NREDEP).

Competencies are also difficult to measure (Barney, 1996). Few studies have developed competence variables based on the experience of firms in the given transaction (Farjoun, 1994; Robins and Wieserma, 1995). To measure the need for *complementary competencies*, the technical directors were asked if they thought that their company had enough competencies to develop the technology by itself, or if there was a need to acquire external competencies. The five-point scale was from 'enough competencies internally' to 'need for external competencies' (COMP).

For technological uncertainty, two distinct measures were used to assess the level of innovation and the level of competition. To determine the level of innovation I measured the *technological lifecycle stages* (LIFEC) (Brokhoff, 1992). Five stages of the lifecycle of the technology were distinguished on a five-point scale where 1 = decline, 2 = maturity, 3 = industrial development, 4 = development and 5 = research. The technical directors were asked to cross the relevant category for the technology at stake. To determine the volatility of the environment we measured the level of *technological competition* (COMPT) by asking the technical directors if they considered that the technology was competing with other technologies for processing the same type of waste on a five-point scale from 'not competing' to 'competing' (COMPT). All the variable's definitions and theoretical ranges are reported in Table 2.

Concerning *regulatory uncertainty*, following the work of Combier (1994), I asked the technical directors to rank the probability that they will have to update their technology because of new regulatory constraints on a five-point scale from 'low probability' to 'high probability' (REGUL).

To assess the level of *strategic importance* of the technology for the company, the technical directors were asked to rank the level of strategic content of the technology at stake on a five-point scale from 'not strategic' to 'very strategic' (STRAT).

To control for extraneous effects, I included in the model 'objective' variables (i.e. not based on manager's perceptions) representing the annual revenue of the company (TURN), its degree of internationalization (INTER) and the specialization of the company in waste management as its first competency (GGD) compared to chemical and engineering industries, equipment manufacturers or other types of firms.

4.2 Model

The dependent variables (tacitness, complexity, transaction difficulty, redeployability of specific investment, technological competencies, regulatory uncertainty, technological stage, technological competition and strategic importance) are used to predict the choice of governance structure (vertical integration, alliance or contract) for the acquisition of technology. Because the category-dependent variable can take one of three values, multinomial logit (MNL) is used for the statistical analysis. This model is estimated using the LIMDEP package (see Green, 1992, for a discussion of this procedure).

5. *Results and Discussion*

Table 2 provides descriptive statistics and Table 3 provides correlations among the independent variables. Table 4 reports the coefficients of the multinomial logit. The set of multinomial logit regression coefficients resulting when contract was used as the reference class (contract = 0) is listed in the first two columns. The coefficients when vertical integration is used as the reference class (vertical integration = 0) are in the third and fourth columns. In the first two columns, a positive sign means that an increase in the variable increases the probability of the technological acquisition by vertical integration or alliance, rather than through contract.

The sum of predicted variables is 273 out of a total of 434, 63% of the observed values, which seems to be a remarkable result in the context of the analysis. Indeed, in the context of an emerging industry where uncertainties are high, our model seems to depict quite well the rationality of manager choices.

Hypothesis 1 predicts a positive relation between the tacitness of the technology and alliance as compared to contract. The variable which represents the tacitness of the technology (TACIT) has a positive sign and is significant for alliance compared to contract with 0.82. Therefore hypothesis 1 is confirmed.

Hypothesis 2 predicts a positive relation between the complexity of the technology and alliances as compared to contract. The complexity of the technology (COMPX) has a negative sign for alliance compared to contract and is not very significant –0.89. This can be explained by a correlation between the variables TACIT and COMPX that is quite high. Regressions have been run without TACIT and/or COMPX and show no noticeable change in the coefficient of the other variables. Hypothesis 2 is not confirmed.

Hypothesis 3 predicts a positive relation between transaction costs and

Table 3. Correlations

	SHIFT	NREDEP	TACIT	COMPX	REGUL	COMPT	LIFEC	COMP	STRAT	TURN	INTER	GGD
SHIFT	1.000											
	525											
NREDEP	0.145	1.000										
	0.001											
	483	485										
TACIT	0.385	–0.057	1.000									
	0	0.208										
	525	484	721									
COMPX	0.404	0.084	0.626	1.000								
	0	0.064	0									
	525	484	721	722								
REGUL	0.367	0.013	0.372	0.331	1.000							
	0	0.775	0	0								
	523	483	638	638	638							
COMPT	0.189	0.071	0.165	0.158	0.044	1.000						
	0	0.118	0	0	0.267							
	522	482	703	703	632	719						
LIFEC	0.22	0.121	0.4	0.335	0.312	–0.079	1.000					
	0	0.008	0	0	0	0.035						
	522	482	708	708	636	718	724					
COMP	–0.082	–0.241	0.171	0.116	0.068	0.112	–0.037	1.000				
	0.06	0	0	0.002	0.086	0.003	0.329					
	524	484	696	696	638	690	694	696				
STRAT	0.179	0.001	0.257	0.256	0.115	0.228	–0.052	0.211	1.000			
	0	0.979	0	0	0.004	0	0.181	0				
	525	484	676	676	636	668	673	662	676			
TURN	0.12	–0.19	0.099	0.043	0.106	0.016	0.085	–0.004	0.019	1.000		
	0.008	0	0.01	0.259	0.01	0.674	0.026	0.915	0.626			
	484	446	680	681	597	678	683	655	635	1164		
INTER	–0.085	0.007	0.06	0.027	0.3	–0.021	–0.008	–0.006	–0.159	0.288	1.000	
	0.05	0.876	0.109	0.469	0	0.573	0.831	0.873	0	0		
	525	485	721	722	638	719	724	696	676	1164	1690	
GGD	0.086	–0.012	–0.03	0.029	0	–0.167	–0.01	–0.218	–0.125	–0.158	–0.09	1.000
	0.048	0.797	0.427	0.435	0.995	0	0.787	0	0.001	0	0	
	525	485	721	722	638	719	724	696	676	1164	1690	1690

alliances as compared to vertical integration. The variable for the level of transaction costs (SHIFT) is positive and significant for alliance compared to vertical integration (1.06). This confirms hypothesis 3. SHIFT is also positive and significant for alliance compared to contract (0.86). This is explained by the fact that the contracts in the sample were used for transactions with a lower level of tacitness and complexity, and therefore a lower level of asset

TABLE 4. Equation

Hypothesis	Variable	Reference: contract		Reference: vertical integration	
		Equation (1)		Equation (2)	
		Vertical integration	Collaboration	Collaboration	Contract
	Constant	–0.44 (–0.57)	–0.64 (–0.86)	–0.20 (–0.24)	0.44 (0.57)
H1	TACIT	1.02 (1.84)**	0.82 (1.56)*	–0.20 (–0.34)	–1.02 (–1.84)**
H2	COMPX	–0.28 (–0.46)	–0.89 (–1.51)*	–0.60 (–0.96)	0.28 (0.46)
H3	SHIFT	–0.20 (–0.41)	0.86 (1.83)*	1.06 (2.05)**	0.20 (0.41)
H3	NREDEP	0.19 (0.43)	–1.07 (–2.40)**	–1.26 (–2.58)**	–0.19 (–0.43)
H4	COMP	2.01 (4.44)**	–0.05 (–0.12)	–2.06 (–4.34)**	–2.01 (–4.44)**
H6	LIFEC	–0.11 (–0.15)	1.65 (2.52)**	1.76 (2.32)**	0.11 (0.15)
H6	COMPT	–1.26 (–2.75)**	0.31 (0.73)	1.57 (3.30)**	1.26 (2.75)**
H7	REGUL	–1.00 (–2.04)*	0.32 (0.68)	1.33 (2.57)**	1.00 (2.04)*
H8	STRAT	2.60 (5.61)**	1.15 (2.44)**	–1.45 (–2.87)**	–2.60 (–5.61)**
	TURN	–0.78 (–1.60)*	–1.53 (–3.08)**	–0.75 (–1.43)*	0.78 (1.60)*
	INTER	0.86 (2.46)**	–1.04 (–2.61)**	–1.91 (–4.53)**	–0.86 (–2.46)**
	GGD	–1.63 (–5.10)**	0.37 (0.98)	2.00 (5.41)**	1.63 (5.10)**

t statistic in parenthesis. $*P < 0.10$; $**P < 0.05$.

specificity than alliance transactions. The variable NREDEP, which represents the non-redeployability of the investment, has a negative and significant sign for alliance as compared to vertical integration (–1.26). This could mean that firms are making less specific investment in alliances than inside the firm to avoid transaction costs. We also find that NREDEP has a negative and significant sign for alliance as compared to contract (–1.07). This is an interesting result showing that firms are making more ‘specific’ investments in contracts and would contradict TCE. It illustrates how difficult it is to apprehend the concept of ‘asset specificity’ and its linkage to transaction cost. Indeed, asset can take several forms (human, capital, etc.). In the case of the development of new technologies, as we mentioned before, there is an important amount of investment in 'human capital' or 'knowledge'. This type of asset, although 'specific' to the transaction, is in fact meant to be redeployable. Knowledge provides the capacity for organizational action and new knowledge provides the capacity for organizational renewal. Knowledge acquired has to be useful for future introduction of other technologies and products. It is seen to generate platforms to expand into other markets, i.e. redeploying competencies from one concrete economic setting to another. The results show that alliances are favored for tacit and complex competencies, which can be seen as 'redeployable'. On the other hand, contracts are chosen for formalized and mature technologies and, therefore, for specific investments that might not be redeployable to other uses but for which there might be a market. The low correlation between the variables NREDEP, COMPX and TACIT is an indication of this, showing that complex and tacit competencies are not seen as non-redeployable.

Hypothesis 4 predicts a positive sign between the need for complementary technologies and the use of alliances as compared to vertical integration. The level of competencies (COMP) is negative and significant for alliance compared to vertical integration (–2.06). This means that firms with a high level of competencies (no need for complementary technologies) will prefer vertical integration as compared to alliance. Therefore, the need for competencies is positively linked to alliances. COMP proves to be the most significant of the variables in the model, confirming the importance of building competencies in the choice of alliance. This confirms hypothesis 4.

Hypothesis 5 predicts a positive sign between technological uncertainty and alliance as compared to vertical integration. The variable representing new technologies, LIFEC, is significant and positive for alliance compared to vertical integration (1.76). LIFEC is also significant and positive for alliance compared to contract (1.65). This would seem to confirm that licensing to another firm, because it does not lead to the acquisition of new knowledge by the licensing firm, is often regretted when the market opens up or grows rapidly (Larsson e*t al.*, 1998). LIFEC is one of the most important variables in our model, showing the primary role of new technologies in the choice of governance structure in this industry. The variable which represents technological competition (COMPT) shows a positive and significant sign when alliance is compared to vertical integration (1.57). Therefore, hypothesis 5 is confirmed. The difference between alliance and contract is not very significant and contract is preferred over vertical integration (1.26). This is explained by the fact that the variable COMPT represents two types of technologies, recently developed and mature. Therefore, to assess the technological uncertainty, it is necessary to combine LIFEC and COMPT.

TABLE 5. Computed Probabilities

GOV	Collaboration	Vertical integration	Alliance	Contract
Constant	–0.2	1	1	1
TACIT	–0.2	1	1	0
COMPX	–0.6	0	0	1
REGUL	1.33	0	1	1
COMPT	1.57	0	1	1
LIFEC	1.76	0	1	0
COMP	–2.06	1	0	0
SHIFT	1.06	0	1	0
NREDEP	–1.26	1	0	1
STRAT	–1.45	1	1	0
TURN	–0.75	0	0	1
INTER	–1.91	1	0	0
GGD	2	0	1	1
Sum		–7.07	5.87	2.09
Numerator		0.00	354.25	8.08
	Contract			
Constant	0.44	1	1	1
TACIT	–1.02	1	1	0
COMPX	0.28	0	0	1
REGUL	1	0	1	1
COMPT	1.26	0	1	1
LIFEC	0.11	0	1	0
COMP	–2.01	1	0	0
SHIFT	0.2	0	1	0
NREDEP	–0.19	1	0	1
STRAT	–2.6	1	1	0
TURN	0.78	0	0	1
INTER	–0.86	1	0	0
GGD	1.63	0	1	1
Sum		–6.23	1.02	5.20
Numerator		0.00	2.77	181.27
Denominator		1.00	358.02	190.36
Prob. collab.		0.00	0.99	0.04
Prob. contract		0.00	0.01	0.95
Prob. vert. int.		1.00	0.00	0.01
Total		1	1	1

According to hypothesis 6, with more regulatory uncertainty, there will be more use of alliances than vertical integration. REGUL, representing the level of regulatory uncertainty, has a positive and significant sign as compared to vertical integration (1.33). Hypothesis 6 is therefore confirmed.

Hypothesis 7 predicts a positive link between the strategic importance of the technology and the use of alliance as compared to contract. The strategic importance of the technology variable, STRAT, has a positive and significant sign for alliance compared to contract (1.15). Hypothesis 7 is therefore confirmed.

Concerning control variables, for companies with high annual revenue (TURN), as well as a high level of internationalization (INTER), the sign is positive and significant for vertical integration compared to alliance and, similarly, for contract compared to alliance. Firms specializing in waste management (GGD) prefer to use alliances or contracts rather than vertical integration as shown by the positive and significant sign of alliance and contract compared to vertical integration.

Although most of the hypotheses are confirmed, some are not (e.g. hypothesis 2). Furthermore, the way the results are presented in the equations (where each of the variables are taken independently) does not provide an explanation of the combination of several variables. The most interesting results of our model are found when several variables are taken at the same time and levels are given to each variable to compute the probabilities as shown in Table 5.

With a probability of 100%, Vertical integration is favored for a high value attributed to TACIT, COMPX, NREDEP, COMP, STRAT and INTER, and a low value (0) to COMPX, REGUL, COMPT, LIFEC, SHIFT and TURN. There is a probability of 95% that contract will be chosen for a high value attributed to the variables COMPX, REGUL, COMPT, NREDEP, TURN and GGD, and a low value to the variables TACIT, COMP, LIFEC, STRAT, SHIFT and INTER. There is a probability of 99% for alliance when a high value (1) is attributed to TACIT, SHIFT, LIFEC, COMPT, REGUL, STRAT and GGD, and a low value (0) is given to COMPX, COMP, NREDEP, TURN and INTER. This confirms my hypotheses that alliances, though entailing high transaction costs, are chosen to access complementary competencies in order to develop strategic technologies that are highly tacit and considered redeployable in an environment marked by high technological and regulatory uncertainty.

5.1 Discussion

The results of this analysis support transaction cost hypotheses for vertical integration and contract. Firms will develop tacit and complex technologies inside the firm when they perceive the environment as stable. Firms will acquire the technology through contracts for mature technologies in an environment marked by many competitors. The high transaction costs of alliances for a transaction with a high level of asset specificity is also confirmed.

The results show the difficulty of approximating the notion of asset specificity in the context of knowledge. Knowledge might be specific to a transaction but is seen as a tool to be redeployed for other uses. It is, therefore, not the 'non-redeployability' of the investment that might lead to high transaction costs, but rather the wide range of interorganizational linkages necessary for the transfer of tacit competencies that might facilitate the development of opportunistic behavior and lead to high transaction costs.

Hypotheses derived from the dynamic capability approach find strong support as the results show that the search for competence is a major determinant of governance structure choices. Firms will rely on vertical integration when they possess high technological competencies. Collaborations and contracts will be the preferred means of acquiring complementary technologies. Indeed, although technical directors are aware of the transactional difficulties that could result from alliance, the need for complementary competencies proves to be more important in their governance structure choices. By combining some of the incentive capabilities of markets with the monitoring capabilities and administrative controls associated with hierarchy (internal organization), alliances can provide a superior means of gaining access to technological and other complex capabilities.

In this sense, the view that is put forth is compatible with the dynamic perspective on the growth of the firm. Firms compete on the basis of the superiority of their information, know-how and their abilities to develop new knowledge through experiential learning. The limiting factor on their growth is not only the competitiveness of other firms and the demand of the market, but also the extent to which their advantage can be better replicated by themselves than by competitors.

The creation of capabilities with long-term payoffs is more difficult in dynamic contexts. In highly competitive conditions, the battle for survival concerns the speed with which new organizational practices are adopted. I have showed how the shifting character of the environment is an important determinant of the choice of flexible governance structures. In dynamic contexts marked by high uncertainty concerning the development of new technologies, alliances provide the opportunity to firms to react promptly to external stimuli, at the same time reducing internal investments, thus minimizing the risk of sunk costs should the need arise for strategic readjustment.

In conclusion, the results indicate that firms will rely on alliances for tacit technologies in highly uncertain environments. Although incurring high transaction costs, collaborations are perceived as possessing the flexibility and adaptability necessary to build competencies and to gain a competitive advantage. I am therefore able to test the relationship between organizational choices, uncertainty perceptions, technology and firm attributes.

6. *Conclusions*

Observing that some activities are being outsourced in ways which appear to involve enormous transactional hazards, this paper suggests that the TCE framework, originally formulated in an environment of mature, physical capital-intensive industries, may find limited application in environments where know-how is the key asset, where building rather than protecting specific assets is the main issue, and where technological and regulatory uncertainty is high.

The dynamic capabilities approach provides an interesting framework to show that the essence of the firm rests in its ability to achieve organizational coordination and learning in complex and ever-changing environments. I point out the importance of organizational competence, and more specifically of transactional competence (deciding whether to make or buy, and whether to do so alone or in partnership), to gain a competitive advantage in highly uncertain environments.

Concrete understanding of why firms engage in technological alliances provides additional insights to a purely theoretical understanding of alliances as an alternative to both markets and hierarchies. This paper has argued that even though technological alliances may have higher governance costs than internal development, in a specific context their virtues make them very attractive to managers. In an emerging industry, they facilitate the creation and diffusion of strategic competencies when the sources of knowledge are dispersed among several partners.

Thomson wrote, ‘uncertainty appears as the fundamental problem for complex organization, and coping with uncertainty, as the essence of the administrative process’ (Thomson, 1967, p. 159). This research has been empirically tested in the North American and European waste management industry—a sector encompasses most of the uncertainties described in the literature on industry lifecycles (Klepper, 1997). The work should be particularly useful to understanding an increasing number of industries since business has to face many uncertainties in a hypercompetitive world where a condition of constant disequilibrium and change prevails (D’Aveni, 1994). The firm’s environment is more and more marked by short product lifecycles, short product design cycles, new technologies, frequent entries by unexpected outsiders, repositioning by incumbents, and radical redefinitions of market boundaries as diverse industries merge. In such a context, firms that continue to survive have an internal selection environment that reflects the relevant selection pressures in the external environment, and therefore produce externally viable new strategic variations that are internally selected and retained. It is therefore necessary for research in strategic management to be able to measure how the environment is perceived as well as the links between perceptions and firm strategies.

The questionnaire is particularly interesting because it measures how technical directors in charge of the development of waste treatment technologies perceive the regulatory and technological uncertainty according to the technology at stake, the country, the size of the firm as well as the technological competencies of their firm. Using a multinomial logit, I find strong support that the governance structure for technological acquisition is linked to the perception of uncertainty and the competencies of the firm.

The respondents selected (technical directors in charge of the development of waste treatment technologies) were, I believe, appropriate information sources. One could question their ability to reconstruct the decision at the time that the selection of an internal development, alliance or contract was actually made. Perhaps subsequent experience in some way biased recollection of the decision variables tested.

This approach seems particularly well suited in the context of an emerging industry where choices are taken with limited information. It shows that in such an uncertain environment, managers will prefer governance structures that provide them with enough flexibility to react to unforeseen changes.

I have treated alliances as a unidimensional phenomenon, partly due to sample size limitations for analysis. Further research could benefit from separate analyses by type of alliance and patterns of alliance terms and conditions. One possibility would be to separate horizontal alliances (between competitors), vertical alliances (firms operating at adjacent stages of the value chain), lateral alliances (with firms from other industries) and extended alliances (with regulators and NGOs). It might be particularly useful in this perspective to study multilateral alliances or networks (Clarke and Roome, 1995).

In this industry, as I pointed out, the links of firms with the institutional set-up are very important. Regulatory uncertainty has proven to play a significant role in a firm's decisions to form alliances. Another interesting route could focus on alliances with non-profit organizations. Although the basic tenet of corporate social responsibility is that society and business are tightly interwoven (Wood, 1991), scholars are still struggling to specify the precise mechanisms linking firms and society.

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