The coevolution of industry-university relationships and firm strategy: evidence from the forest products industry

Julio A. Pertuze[1,2]

1. PhD Candidate, Engineering Systems Division, Massachusetts Institute of Technology, Cambridge, MA 02142, USA
2. Assistant Professor, Industrial and Systems Engineering Department, Escuela de Ingenieria, Pontificia Universidad Católica de Chile, Santiago, Chile

Abstract

While there is consensus that university relationships have positive effects on the firm's innovative performance, few studies have analyzed university relationships in terms of the strategy of the firm. In this paper we analyze the strategic trajectories of nine European and North American forest products companies, distilling four generic firm strategies. We contrasted those strategies to each company's university relationships as judged by the firm's publications records. We found that firms were particularly likely to form new university relationships when (1) integrating new positions in the value chain, (2) diversifying their industrial base, or (3) internationalizing the manufacturing base. On the contrary, when firms narrowed their business base or contracted geographically, they reduced university links. Based on these observations, we derived a theoretic framework addressing how industry-university relationships evolve with changes in firm strategy.

Resumen

Si bien hay consenso que las relaciones universitarias tienen efectos positivos para la innovación en las empresas, pocos estudios han analizado estas relaciones en función de la estrategia de la firma. Este articulo analiza las trayectorias de nueve empresas de productos forestales de Norteamérica y Europa, encontrando que éstas utilizan cuatro estrategias genéricas. Contrastamos estas estrategias con las relaciones universitarias de éstas empresas, basándonos en las publicaciones científicas escritas en conjunto. Encontramos que empresas establecen nuevas relaciones universitarias cuando (1) integran nuevas posiciones de la cadena de valor, (2) diversifican su base industrial, o (3) internacionalizan su base manufacturera. Por el contrario, cuando las empresas reducen sus líneas de negocio o se contraen geográficamente, éstas disminuyen sus vínculos universitarios. Basados en estas observaciones, definimos un modelo teórico que permite analizar cómo las relaciones universidad-empresa evolucionan con cambios en la estrategia de las empresas.

1. Introduction and Objectives

There is broad consensus that industry-university relationships can have positive effects on the firm's innovative performance [1, 2], and that these effects have increased over the last decades [3]. As a result, industry and universities are moving ever closer to each other, and governments are actively encouraging the formation of these links [4-7].

While several scholars have mapped and described different types of industry-university links, few have analyzed these relationships in terms of the strategic choices of the firm [8]. This is important since managerial choice underlies the formation of any university relationship [9], and research alliances are embedded within the firm's strategic portfolio, and thus co-evolve with firm strategy and the competitive dynamics of the industry [10].

This paper seeks to fill this gap by analyzing industry-university relationships in a dynamic context, exploring both the origin of the relationship and its co-evolution over time. In particular, it seeks to answer *how do industry university relationships coevolve with firm strategy?*

To analyze the co-evolution of industry-university relationships, we undertook a longitudinal case study research approach, analyzing nine forest products companies in three different regions: North America, Northern Europe, and Southern Europe. The forest products industry is a classical mature industry, which has been in operations long before forestry or chemical engineering emerged as scientific fields. This provides an interesting research setting for studying the coevolution of industry-university relationships, especially since forest products firms have differed in their competitive strategies over time [11], and have forged different links with several university partners. Table 1 contains a summary description of the firms in the database, and shows how they changed their business lines over time.

Table 1: Firm sample characteristics

Company	Country	Est.	Initial Business	Current Businesses	Sales (US$ 2011)	R&D (US$ 2011)	R&D/ Sales
International Paper	USA	1898	Pulp	Pulp, paper, packaging	$26 B	$13 M	0.05%
Weyerhaeuser	USA	1900	Timber	Timber, pulp, paper, packaging, plywood, engineered woods	$6.2 B	$30 M	0.45%
Domtar	Canada	1903	Chemicals	Paper, Personal Care	$5.6 B	$20 M*	<0.5%*
Portucel Soporcel	Portugal	1953	Pulp	Pulp, Paper	$2 B	$7.6 M	0.38%
Amorim	Portugal	1870	Cork stoppers	Cork stoppers, Raw & Composite materials, Building materials	$0.7 B	$2.8 M**	0.45%**
Sonae Industria	Portugal	1959	Panels	Panels, decorative laminates, chemical resins	$1.8B	$2 M	0.11%
SCA	Sweden	1929	Pulp	Personal Care, Tissue	$16 B	$125 M	0.79%
StoraEnso	Finland	1896	Timber	Pulp, Paper, Timber, Packaging, Joinery, Engineered woods	$14.9 B	$106 M	0.7%
UPM	Finland	1873	Pulp	Pulp, Paper, Timber, Plywood, Labels	$13.7 B	$68 M	0.5%

* Approximate values based on firm interview data
** 2008 values

2. Methodology

2.1. Firm strategy characterization

For each company in the sample, we created a database containing a chronological description of relevant strategic events, including mergers, acquisitions, construction or expansion of facilities, strategic alliances, new products or services, and R&D activities, among other [11, 12]. This data was obtained by analyzing the company's annual reports, and triangulating this information with secondary sources, including journals, press articles, and company historical retrospectives when available. The purpose of this triangulation was to enhance the *reliability* of our research constructs [13]. With this data, we built individual company case studies to describe of the changes in their strategy, and the contextual factors that prompted the different courses of action [14]. Individual case studies were complemented with 20 in-depth, hour-long, semi-structured interviews with senior managers and researchers associated to each of these nine companies. We sought to interview more than one person per company to avoid single-source respondent biases. The final outcomes of this stage were in-depth analytical chronologies of each one of these nine firms [15].

2.2. University Relationships Characterization

To characterize each firm's university relationships, we looked at three complementary areas. First, we analyzed the people flows between the firms and universities. For each company, we distilled the names of the most prolific authors and inventors utilizing corporate publication and patent records. For each person, we analyzed their academic and professional trajectories utilizing several data sources including online social media (e.g. LinkedIn), public university records (e.g. thesis repositories), and biography databases (e.g. Marquis Who is Who) among other public sources. We also checked for additional patents and publications made under different organizational names, as this paper trail is useful for inferring pre or post employers. In total, about 900 names were examined, 600 of which corresponded to company researchers, and the remaining to university academics or other company coauthors.

Second, we analyzed the firm's technological priorities and university links based on patents and publications records. Patent records were useful for characterizing the technological priorities, however, they were not useful for inferring university relationships. The companies in the dataset have patented less than 20 inventions in collaboration with universities. Publication records, on the other hand, were useful for inferring industry-university relationships. In total, the companies in the dataset have coauthored approximately 1,300 papers with universities. We classified each one of these papers along the firm's value chain to observe which technological areas concentrated university links, and how these relationships evolved over time.

Finally, we analyzed how firm's university network evolved over time. Utilizing the same co-publication records, we obtained the addresses of the firm's university partners and built a network linking individual company sites with specific universities. We georeferenced this network information on Google Maps, which allowed us to observe and assess the effects of geography on industry-university links.

3. Results

After analyzing the companies' historical trajectories, we distilled four generic firm strategies: Integration, Diversification, Internationalization, and Focalization (See Figure 1). Each of these strategies could be related to transformations in the firm's university relationships.

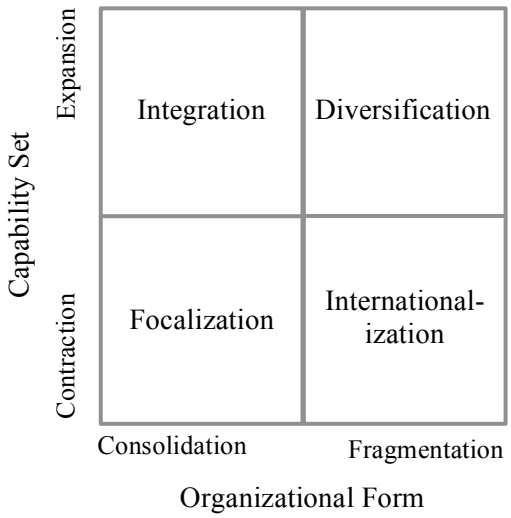

Figure 1: Four generic forest product firm strategies

Integration refers to the expansion of a firm's capability along an existing value chain. This usually takes the form of mergers or acquisition of some of the firm's suppliers or distributors (i.e. vertical integration) or with some of the firm's competitors (i.e. horizontal integration). This strategic decision is often pursued as a means to achieve more of control over the value chain [16]. There is thus consolidation of different segments of the value chain under a new organizational form, and an expansion of the firm's capability set towards new knowledge areas.

Diversification refers to the expansion of a firm into new businesses and industries. When firms diversify, they expand their capability set in different technological trajectories. As a result of this diversification, firms usually create new divisions or technological units to accommodate new business lines, which can cause a fragmentation of the firm's internal environment.

Internationalization refers to the geographic expansion of a firm's manufacturing base, which causes a fragmentation in the firm's organizational form. In addition, the decision of a firm to expand internationally can come at the cost of contracting the firm's capability set, as firms need to free resources for financing the expansion

Focalization refers to the contraction of a firm's capability set and the consolidation of the firm's organizational form. This usually takes the form of closure of divesture of existing company business lines, or by withdrawing their operations from different countries.

3.1. Effects of Integration

Our research found that when companies' integrated new positions of the value chain, they also tended to form new university connections, which suggests a positive relationship between vertical integration and firm's university links. For example, when pulp firms integrated into paper production, we observed new university relationships regarding the manufacturing of paper. The same was true for firms moving down the value chain acquiring forestlands to supply their mills. New connections with forestry schools were formed to increase the yield of these lands.

The increased number of university connections in periods of integration was usually the result of company acquisitions and new personnel hires. For example, we found several cases in which firms acquired other companies with existing R&D facilities and personnel that were later merged to the company's existing R&D labs. These people usually continued working with their prior university partners.

The positive relationship between integration and university relationships can be easily observed by analyzing the distribution of industry-university co-publications along the firm's value chain. In Figure 2, for example, we plotted the different articles coauthored between Domtar, a vertically integrated pulp and paper manufacturer, and universities. As observed in the figure, university research has contributed to different segments of the firm's value chain, including forestry, pulp, and paper production. We can also observe how the firm's research interests have evolved over time. In the 1970s, for example, the firm had research collaborations with universities in the areas of forestry and waste management. More recently, the company has been collaborating with universities in finding alternative fiber sources, and on improving the manufacturing of fine papers.

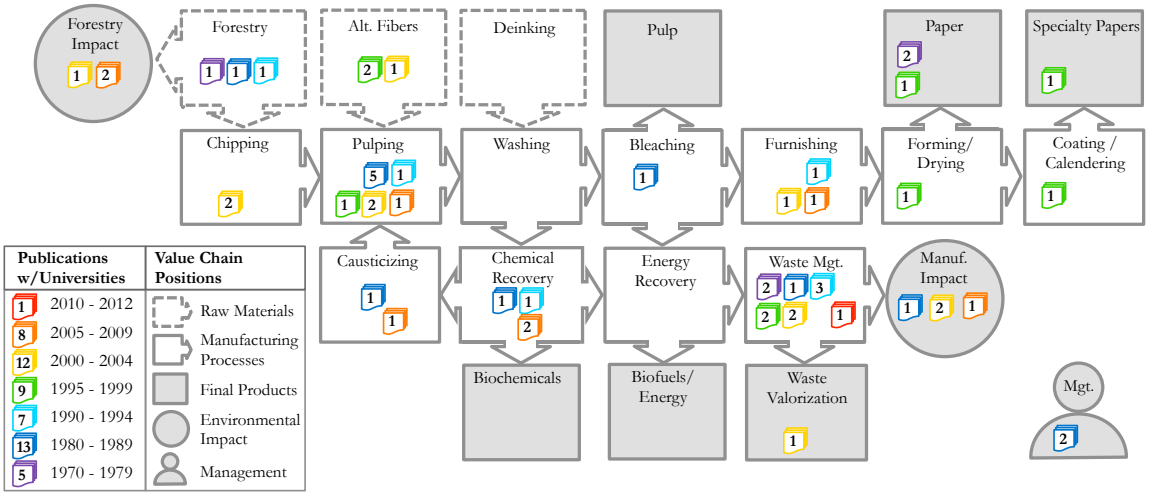

Figure 2: Evolution of Domtar's university relationships along the pulp and paper value chain

3.2. Effects of Diversification

When companies diversified, they also formed new university relationships as a means to acquire and support the technological base of these new units. This suggests a positive relationship between the diversity of business lines and the firm's university links.

The positive relationship between diversification and university relationships can be easily observed by analyzing the distribution of industry-university co-publications along the different industries in which the firm participates. Figure 3 shows, for example, the distribution of SCA's university co-publications along the different industries served by this firm.

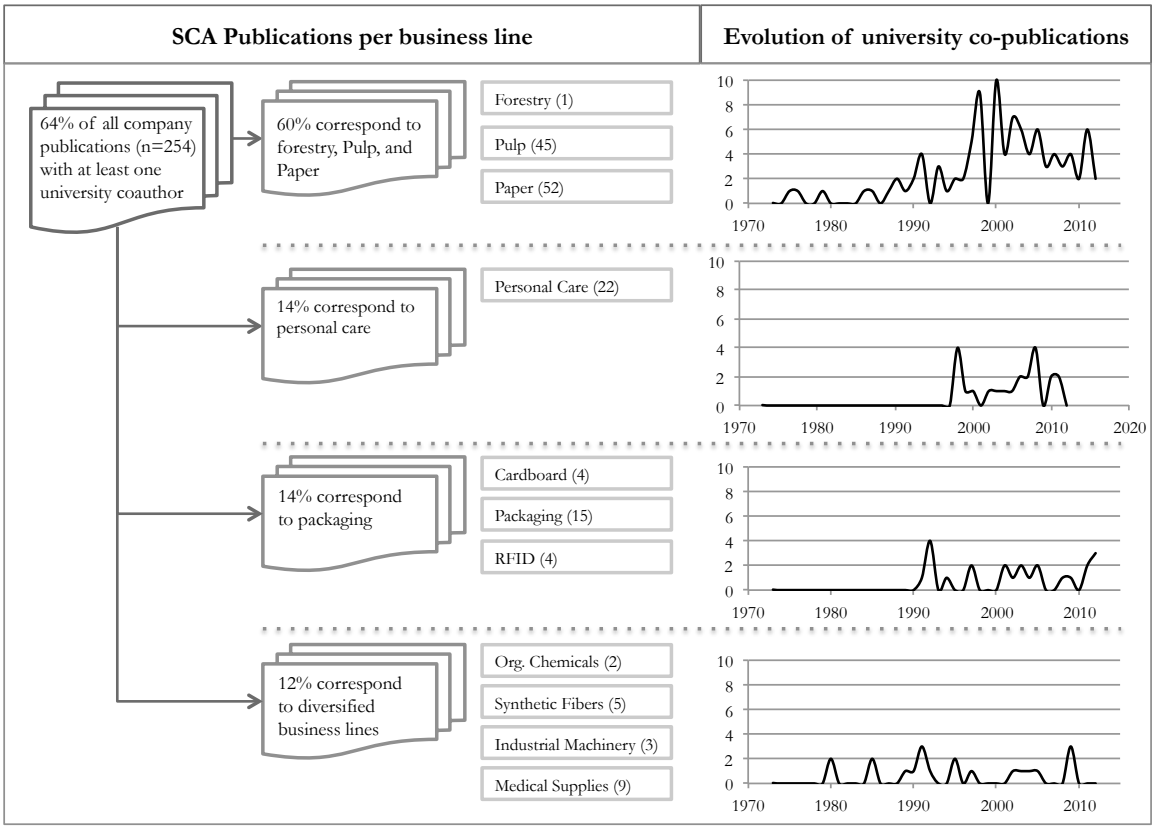

Figure 3: Distribution of university co-publications along SCA's industrial base

Not all diversified business lines, however, were equally likely to form a university relationship. Some industrial sectors draw more heavily on scientific knowledge and thus universities are an important source for technological advancement. Other sectors, however, rely more on the technological advances of firms up and down their value chain, and thus universities play a secondary role [17]. For example, while some of the firms in our dataset diversified into real estate management, housing, and financial services, we did not observe new university publications in these areas, which is consistent with the literature that has found that the service sector less likely than the industrial sector to engage in research collaborations with universities [18, 19].

3.3. Effects of Internationalization

Internationalization refers to actions aimed at establishing manufacturing operations in new countries or regions (not to be confused with exports). Our research found that when firms internationalize, they tend to form new university links in the host country for

recruiting and research purposes. This suggests a positive relationship between the geographic diversity of the firm's operations and their university links.

UPM presents a good example of a company that has been internationalizing and opening new manufacturing plants and research centers in different countries. Historically, the company's university connections have been with universities and research institutes in Finland, as shown in the upper right section of Figure 4. Since the 1960s, however, the company has been expanding through different periods of internationalization. In 1966, for example, the company expanded into Germany and during the late 1980s, UPM expanded into the United Kingdom. More recently the company has been expanding into Canada, China, and Uruguay as shown in the lower section of Figure 4.

UPM's territorial expansions have often translated into new university linkages ash shown in Figure 4. In 2007, for example, the company opened a research center near Shanghai. According to the VP for Business Development: *"The new R&D Center in China will enhance [UPM's] competitiveness in local product applications and in the use of locally available fiber resources. We also want to increase our cooperation with local research institutes and universities in this field."* Recently the company has also opened an R&D center in Uruguay in 2012, the Director for Latin American Business mentioned *"The center aims to strengthen fiber research in plant species growing in the southern hemisphere"…"in addition, the aim is to increase cooperation with research institutes and universities in Uruguay."*

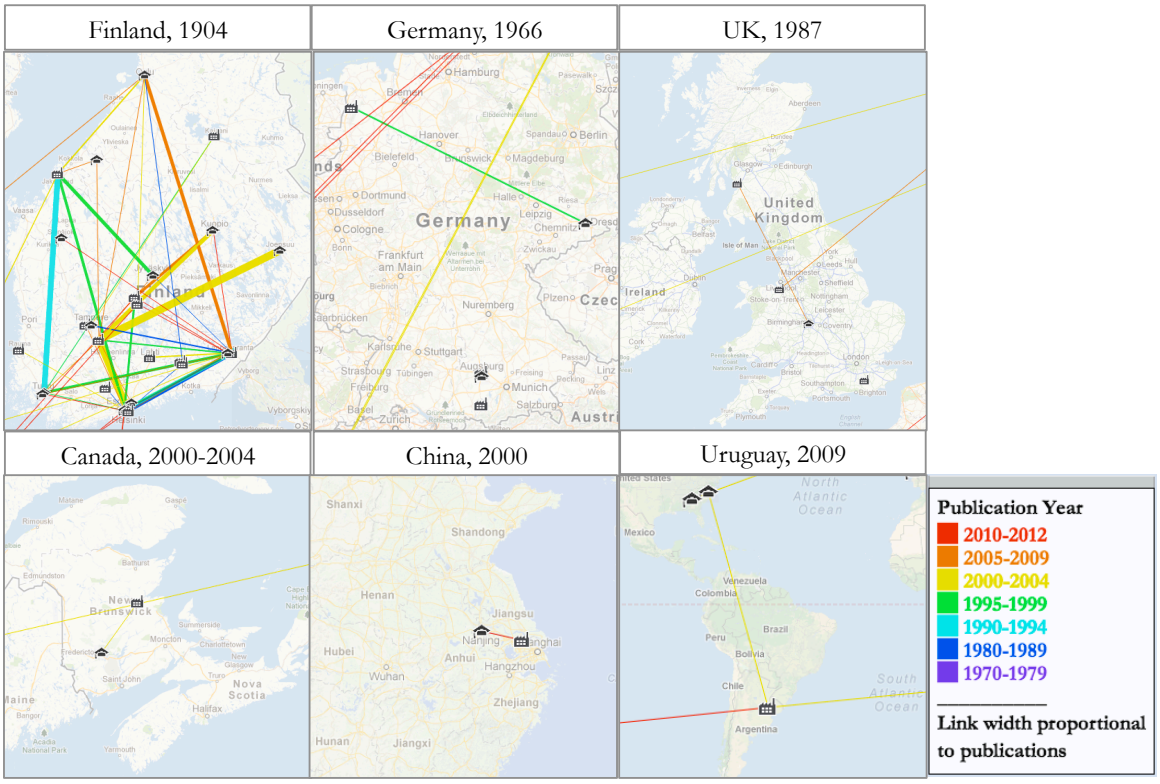

Figure 4: UPM's manufacturing internationalization

3.4. Effects of Focalization

When firms narrowed their product base and/or contracted geographically, we observed they also narrowed their university relationships. This reduction was usually the result of business unit divestures or R&D personnel layoffs.

SCA presents a good example of a company undergoing this type of strategic transformation. Since 2007, the company has been divesting its packaging operations to concentrate on personal care and hygiene products. In June 2012, for example, SCA announced the complete divesture of its packaging business, and this had consequences for the company's R&D and university relationships. Shortly after the divesture, SCA announced a 25% reduction of their research staff at the Sundsvall research center. According to the press release: *"A substantial part of (SCA's Sundsvall) R&D operations have been on packaging and packaging paper, but after SCA's divestment this summer of its entire packaging operations, the need of research in these areas is drastically reduced"* [20]. As shown earlier in Figure 3, 14% of SCA's university co-publications have been in the area of packaging. We expect to see a reduction in the number of university relationships in this area as a consequence of the divesture and reduction in packaging R&D.

4. Inductive Model

In the previous section, we showed that when firms grew by integrating new positions in the value chain, diversifying their industrial base, or by internationalizing the manufacturing base, they were likely to form new university links. We also showed that when firms narrowed their product or geographical scope, they also narrowed their university network. An underlying question, however, is what are the effects of periodic transitions between these 4 strategies on the firm's pre-existing university relationships. In this section we derived a theoretical framework based on the observation that not all industry-university relationships were equally affected after a change in the firm's strategy.

From an organizational standpoint, the concept of coupling has been found useful for describing how two organizations interact with each other [21]. The coupling between two organizations can be characterized along two dimensions: distinctiveness and responsiveness [21, 22] (See Figure 5). Distinctiveness refers to the capacity of organizations to maintain their idiosyncratic behavior. This construct is related to the concepts of institutional separateness and identity preservation[22, 23]. Responsiveness, on the other hand, refers to how changes on one of the organizations affect the other. This construct is related to the concepts of integration [21], interdependence [22], and coordination [24]. Utilizing this framework, we distinguished three different types industry-university systems: decoupled, loosely coupled, and tightly coupled systems. The conceptual difference between these three systems can be observed, for example, by analyzing how industry-university systems react to external stimuli.

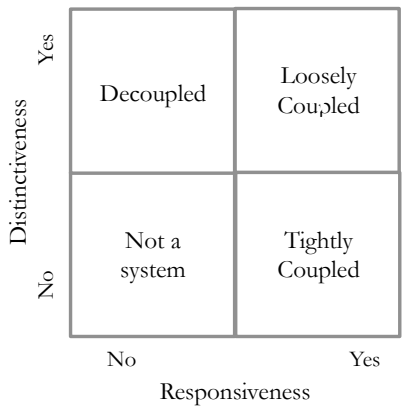

Figure 5: Coupling strength of industry-university systems

In decoupled systems, firms and universities react to environmental stimuli distinctively, but not responsively. For example, the environmental movement of the 1970s prompted several firms to invest in pollution control technologies, and that same movement triggered the formation of environmental research centers at different universities. These two actions were highly idiosyncratic (i.e. distinctive) and at the same time uncoordinated (i.e. not responsive).

In tightly coupled systems, firms and universities react to environmental stimuli responsively and without distinctiveness. Think, for example, on academic startups. Idiosyncratically, an academic startup is similar to the academic research group from which it was spun-off, and thus we would expect their reactions to be indistinctive. In addition, we could expect a high-degree of responsiveness between these two organizations. For example, changes in research funding will affect both the academic research group and the startup that feeds on this academic research. Other examples of tightly coupled systems are industry-funded research centers, or research consortiums. At these hybrid industry-university organizations, there is no distinctiveness between industry or university researchers, and these work coordinately to define and execute a common research agenda, so there is a high degree of responsiveness between the two.

Finally, in loosely coupled systems, firms and universities are responsive to each other, but preserve their own identity and separateness (i.e. distinctiveness). Most of industry-university links fall under this category. In research collaborations, for example, firms and universities work in coordination (i.e. are responsive), and produce research outcomes that are highly idiosyncratic. For example, a joint research project can result in a thesis, which is a distinctive university outcome, and also that project can result in a design concept for an industrial partner.

4.1. Properties of loosely coupled industry-university systems

The coupling and decoupling of industry-university systems can have several implications from a technological standpoint. Some authors, for example, has described that two important organizational outcomes of loosely coupled systems are buffering and persistence [22]. In other words, loosely coupled university systems can neutralize the impact of strategic change by buffering technologies and allowing them to mature longer.

The development of Nanocrystalline Cellulose (NCCs) offers a good example on how loosely coupled industry-university systems can allow technologies to persist and mature.

Nanocrystallyne Cellulose structures (NCCs) were first observed by Bengt G. Rånby in 1949, while working as researcher at the University of Uppsala, Sweden [34]. Rånby was recruited by the American Viscose Corporation in 1957, a US manufacturer of rayon and other cellulose-based chemicals. At this company, Rånby continued working on NCCs in collaboration with Robert H. Marchessault, who was a PhD graduate from McGill University that had previously worked a year as a postdoctoral fellow at the University of Uppsala in 1955 [35].

In 1962 the American Viscose Corporation was sold to the FMC Corporation, and both Rånby and Marchessault moved to the State University of New York. In 1969 Marchessault returned to Canada and joined the University of Montreal. In 1979, however, Marchessault was recruited by the Xerox research center of Canada, where he served as Vice President of research. At Xerox, Marchessault continued conducting research on cellulose and crystalline structures, until he returned to McGill University in 1990. At McGill University, Marchessault began collaborating with Prof. Derek Gray, studying the iridescent properties of NCCs [36]. Dr. Gray, who was also a research scientist at FP Innovation (former Pulp and Paper Research Institute of Canada, Paprican), spent the next years refining the methods for extracting Nanocrystals from wood pulp. Finally, in 2012, FP Innovations made an agreement with Domtar to open the world's first commercial scale NCC plant at Domtar's pulp and paper plant in Windsor.

As presented in this example, NCCs endured several firm strategic changes and also several changes in the universities' research agendas after the mobility of key researchers. This technology was able to survive precisely thanks to this fluid—and loosely coupled—industry-university interfaces. Figure 6 summarizes the different institutions, people, and development paths followed by NCCs.

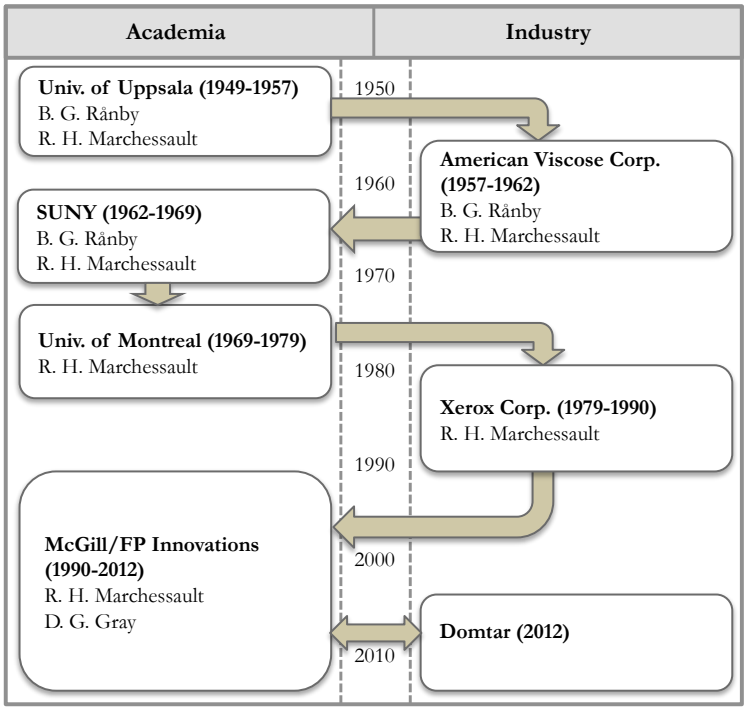

Figure 6: Institutional knowledge flows in the development of Nanocrystalline Cellulose

4.2. Properties of tightly coupled industry-university systems

Tightly coupled systems, on the other hand, facilitate the knowledge creation and transfer process between universities and firms. When firms and universities opt or evolve into more complex organizational structures, they increase interactions and facilitate people flows between their organizational boundaries. These frequent interactions allows researchers to develop a common set of practices, shared experiences, short-hand languages, and a common knowledge base, all of which are known to facilitate the knowledge creation and transfer of process [28, 37].

The problem with tightly coupled system occurs when one of the partners loses interest in the common research agenda. Think of the case of the academic startup. When the star scientist moves to a new university, three things can happen. Either the startup moves to this new location, or it changes its technological focus, or it gets sold or closed. The same has happened to several other tightly coupled industry-university systems. The US Institute of Paper Science and Chemistry, for example, moved from Appleton, Wisconsin, to Atlanta, Georgia, after the pulp and paper deindustrialization of the Great Lakes Region [38]. In other words, while tightly coupled industry-university systems are most effective for transferring knowledge, this effectiveness comes at the cost of loosing the flexibility to adapt to changes.

4.3. Effects of strategic transitions on industry-university coupling

Figure 7 presents a conceptual framework that describes how changes in firm strategy might affect the coupling of industry-university systems. At the center of this model, we represented the three types of systems: decoupled, loosely coupled, and tightly coupled systems.

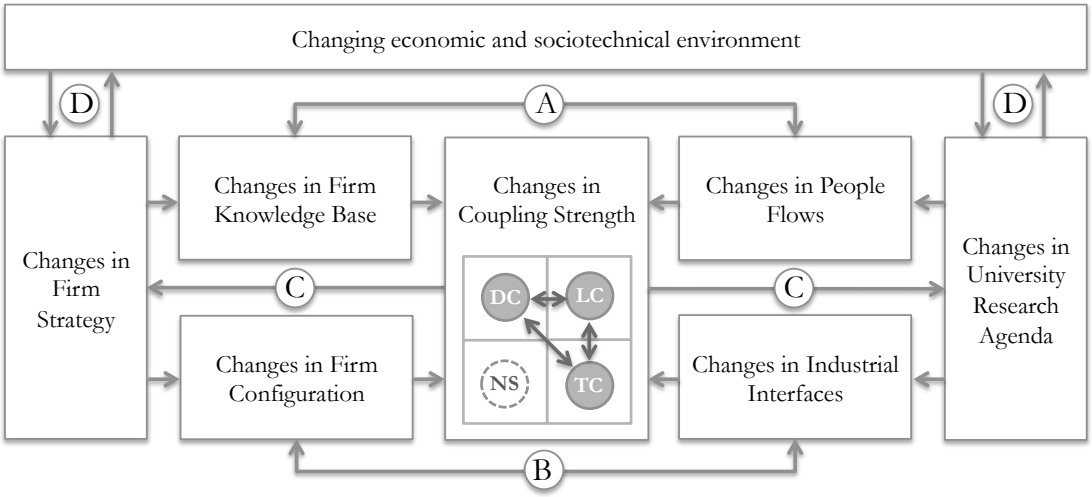

Figure 7: Conceptual framework of strategic change and industry-university relationships adaptation

According to this model, in the absence of strategic change, industry-university system will gradually evolve into tightly coupled structures. There are several trends that support this evolution. First, literature on absorptive capacity has shown that the process of knowledge accumulation is self-reinforcing: the accumulation of knowledge in one period allows a more efficient accumulation in the next [25]. Thus, over time, firms will

increase their knowledge endowments, which in turn will make them more proactive in exploiting external sources of knowledge, such as universities. Thus, a decoupled industry-university system will become loosely coupled over time.

Second, from a cognitive perspective, literature has found that firms search for knowledge in the places where they have had past successes [26, 27], and this search is a socially mediated process: researchers utilize these personal networks for finding collaboration partners [28]. These search routines will strengthen loosely coupled systems.

Third, studies have found that the existence of a previous relationships is positively correlated with the outcomes of subsequent industry-university research collaborations [29]. Thus, positive experiences with a university partner will reinforce the decision of the firm to continue that relationship, strengthening loosely coupled systems.

Fourth, companies' recruit from universities that have developed expertise in knowledge areas relevant for the firm, and company personnel can occupy part-time faculty positions at these universities. These bidirectional people flows will strengthen the coupling between two organizations (see letter A in Figure 7).

Fifth, from an organizational behavior perspective, organizations evolve into hierarchical structures as a means to increase coordination [30]. For example, universities have created technology transfer offices and industrial liaison programs to coordinate their relationships with external firms. Similarly, firms that increase their relationships with a university partner will develop new organizational forms for managing and coordinating these relationships. The creation of these new organizational forms will also strengthen the coupling between two organizations (see letter B in Figure 7).

Firms and universities, however, are embedded in a dynamic environment. Environmental stimuli such as social trends, technological advancements, and political decisions continuously shape industry-university links, and consequently these relationships never reach an equilibrium condition [7]. These environmental stimuli can prompt firms to change strategy, and at the same time, these events can prompt universities to change their research agenda (see letter D in Figure 7).

When firms change strategy, they modify their knowledge base and organizational form, which also modifies their absorptive capacity [31]. Changes in the firm's absorptive capacity, in turn, can have rippling effects on universities depending on the coupling strength of the system (see letter C in Figure 7). For example, if a firm and a university had formed a tightly coupled system in support of a particular technological area and if the firm decides to exit that area, then the university's research agenda will be negatively affected. Specifically, universities will reduce their research staff and educational programs in that area, and might also modify their industrial interfaces in response to a declining firm demand. Thus, tightly coupled industry-university systems can become loosely coupled or decoupled over short periods of time. On the other hand, if a firm and a university had formed a loosely coupled system, those same changes in firm strategy would have a smaller effect on the university's research agenda, because one of the properties of loosely coupled systems is their resistance to change [22].

5. Conclusions

The goal of this paper was to answer how industry-university relationships coevolve with changes in firm strategy. After analyzing the historical trajectories of nine forest products companies, we found these firms alternated between four generic strategies: Integration, Diversification, Internationalization, and Focalization. We analyzed the transformation of each company's university relationships under each of these four strategic periods. We found that when firms grow either by integrating new positions within the value chain, by diversifying their product base, or by extending the geographical outreach of their manufacturing operations, they also formed new university connections. On the contrary, when firms decide to focalize and narrow their product or geographical scope, they reduced their university connections. This finding contrasts with the literature on strategic alliance formation, which has found that the rate of external alliance formation is greater when firms are in difficult market situations [39]. Our research suggests the opposite. When forest products firms were in weak strategic positions, they narrowed their business base and reduced university links.

A second finding refers to the locus of the firm's absorptive capacity. While this construct has traditionally been modeled in terms of the firm's R&D intensity [25], our research suggests that the firm's ability to take advantage of external knowledge is also affected by the firm's organizational form, that is, the diversity of the firm's manufacturing operations, and the geographic diversity of these operations. This finding underscores important regional dynamics. If the locus of the firm's absorptive capacity resides in its manufacturing base, then deindustrialization also poses risks for universities and their research agendas with industry.

Finally, we derived a theoretical model describing how periodic transitions between the four firm strategies can have rippling effects on firms and universities depending on the coupling strength of the systems. Loosely coupled systems allowed technologies to mature longer, and tightly coupled systems were more effective for creating and transferring knowledge. More-follow up research is underway to validate this conceptual framework, which we believe can be generalizable to other capital-intensive industries such as the mining or oil and gas industry.

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