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WORKING PAPER SERIES

Technology Strategies in the Knowledge Economy: the Licensing Activity of Himont

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2001/18 November 2001

ISSN (online) 2284-0400

1. Introduction

One of the main changes that the "knowledge-based" economy has brought to international competition and to companies' behaviour regards the importance that intellectual assets, rather than physical assets, have for the competitive advantage of regions and companies. Patents, scientific and technological knowledge in general and human skills are all factors that play a key role in defining firms' profitability and firms' capability to defend their market position. Against this background, the worldwide growing demand for technologies expressed by large and small firms and by other institutions represents a remarkable feature. This process has promoted the setting-up of a variety of solutions for the exchange of technologies and technological knowledge (e.g. joint-ventures, partnerships, licensing, cross-licensing, R&D contracts), and brought to the upsurge and functioning of "markets for technology". The recent evolution of the competitive environment shows that technology trade has undoubtedly become a relevant aspect of the "knowledge-based economy".

Firms are gradually changing their strategies in order to take advantage of the possibility of technology outsourcing, on the one hand, and in order to increase the gains from their R&D activity, by licensing the internally developed technologies to other firms and institutions, on the other. This pattern gave rise to the view that competitive strengths are shifting from technological aspects to different levels of competitive behaviour. Instead of keeping technology secret and using it as a distinctive competence, companies have relatively greater advantages in licensing out their technologies, according to some well defined technology strategy. Indeed, the development and functioning of specialised "markets for technologies" represents a further option for companies, which can think at licensing out their technologies as an alternative, viable solution to acquire rents. At the same time, companies' decision to enter new (technological) markets and to diversify from existing technologies, can be pursued "buying" new technologies directly from the market, at competitive prices. Companies can take advantage of the economies (of specialisation) that can be generated at the industry level. They can exploit more efficient production processes, with advantages in terms of enhanced productivity of downstream investments in their own businesses.

This study analyses determinants and implications of technology trading strategies promoted by large firms. Specifically, it considers the case of large chemical companies and explores the example of one of those companies (Himont), which more than others based its success on technology licensing. This example tries to answer a key question related to technology strategies: Why do (large) firms license out their technologies? It is well known that licensing represents one of the possible means that companies can exploit to capture value from their innovative activity. The possibility to pursue this strategy depends on the existence of a set of conditions, among which Teece (1986 and 1998) has identified the appropriability regimes, the dominant design paradigm, and the presence of complementary assets. These conditions are not easily satisfied. However, more and more companies in the industrialised countries are thinking at licensing out of their unutilised technological portfolio (patents) as a mean to gain financial or economic benefits.

A recent survey conducted on 133 firms and 20 universities from Western Europe, North America and Japan operating in different industrial sectors, shows that nearly two-thirds of organisations have a share of unutilised patents, and one in eight have in excess of 1,000 patents (BTG, 1998). At the same time, most of them find licensing out attractive, primarily because of financial, economic or commercial benefits. Indeed, about two-thirds of organisations reported to license technologies to other organisations. In turn, this implies that the management of technological knowledge and other intellectual property rights is becoming a "core competence" of successful enterprises. This is because, the strategic use of patents, technologies and other intellectual property right can enhance the success of a company in three different ways: a) by stacking out and defending a proprietary market advantage; b) by improving firms' financial performance (realising the "hidden value of patents"); and, c) by increasing firms' competitiveness (Rivette and Kline, 2000). The critical point of this approach is that, once developed, a technology becomes a sunk cost and companies can leverage such a cost as a source of revenues and R&D funding. In these cases, however, in order to avoid an increase in competition in the final product market where the company is currently operating, licensing is usually confined to *old* technologies, to geographically separated markets, or to non-core technologies resulting from processes of technological diversification (Granstrand *et al.*, 1997; Patel and Pavitt, 1997).

If these are the possible advantages coming out from licensing, the question then shifts towards under which conditions licensing out the *latest* technology becomes an optimal strategy. Different explanations can be considered. Arora and Fosfuri (1999), demonstrate that large incumbent firms are willing to license out their technologies to other firms potentially competing with them in the final product market, because of the expected revenues from licensing. Indeed, in some circumstances, the amount of those revenues is greater than the erosion of profits due to other firms competing in the downstream product market – the "revenue effect" is greater than the "rent dissipation effect" –, so that licensing out represents a convenient strategy. This usually happens in the presence of existing technology suppliers providing technologies to potential entrants and thus creating new competitors in the product market and increasing the rent dissipation effect.

In general terms, Arora, Fosfuri and Gambardella (2000) suggest that the decision on whether licensing or exploiting the technology in-house depends on three main factors. First, if the firm has distinctive complementary assets in production and marketing, compared to other competing firms, the efficient strategy is in-house exploitation of technology. On the contrary, licensing might become the right strategy, in order to acquire some rents from innovation. Second, the decision also depends on the nature and importance of the transaction costs involved in the exchange of complementary assets, compared with the importance of transaction costs involved in selling or licensing the technology. If the latter are greater than the former, a company without the needed complementary assets may choose to acquire those assets in the specialised market, and then exploit the technology in-house. This strategy allows firms to save resources, compared with the strategy of licensing, because of the smaller amount of transaction costs. Finally, firms may choose to license their proprietary technologies instead of exploiting them in-house, because of the extent of competition in the final product market. The degree of competition influences the capability for firms of extracting returns, so that the "best strategy" is to operate in the market (technology vs. product market) with the smaller level of competition.

The case of Himont highlights many of these points and gives a partial answer to the previous theoretical models. The sparking condition for licensing was the presence of financial problems which prevented Himont from using its new process technology for polypropylene (PP) production. As suggested by Arora, Fosfuri and Gambardella, without the downstream complementary assets in production, licensing out became the optimal answer in order gain profits from R&D investments, and indeed Himont acted at the beginning as an external technology supplier. Later, other conditions came into play and strengthened Himont's decision to license. First, the presence of other technology suppliers that were creating new competitors in the downstream PP market where Himont was operating. Coherently with Arora and Fosfuri's model, this increased the rent dissipation effect. Second, the demand of plastics (and particularly PP) constantly grew during the 1980s and 1990s, thus leaving space for new firms to serve the market. In turn, this lowered the degree of competition induced from the new suppliers of PP operating with the process technology licensed from Himont itself. Third, as suggested by the model of Khazam and Mowery (1993), Himont aimed at creating a standard of PP in the product market, and this was possible only licensing widely its process technology. Indeed, companies acquiring polypropylene were used to have two to three suppliers, and they were better off if both were using the same technology for making PP. In turn, the presence of many suppliers using the same Himont's technology strengthened the linkage between Himont and its customers (in the product market).

At the same time, the case of Himont has implications for antitrust policy as well. When Montedison decided to merge Himont with Shell, both the European and US regulatory authorities opposed to this decision because it was going to create (and strengthen) a monopoly in the market for process technology. At the best of our knowledge, this was the first case in which problems of monopoly power came not in the market for products – and hence directly linked to customers well-being –, but in the market for technology. And, even more interesting, was the solution that the authorities identified in order to solve to problem.

The remaining of this paper is organised as follows. Section 2 represents an introduction to the issue of technology transfer in chemicals, and offers an empirical assessment of the diffusion of technology licensing in this sector, by highlighting both the role of Specialised Engineering Firms and of large chemical companies. Section 3 discusses the origins of licensing practices in chemicals, by describing the conditions of the knowledge base and of the demand for chemical products. Section 4 focuses on the case of Himont. It firstly describes the main facts of Himont's life, by explaining which "historical accidents" brought Himont to license its proprietary technology. Then, it explores the aspects of the licensing strategy, licensing management and the implication for antitrust policy. Section 5 concludes.

2. Diffusion of technology licensing in the chemical industry

The example of Himont and its licensing activity is not an isolated case in the chemical industry. For reasons that will be discussed in section 3, the existence of a set of conditions in the cognitive space, the solution of transactional problems, and the growing demand of chemical compounds since the Second World War shaped the industry structure and allowed a worldwide division of labour between technology suppliers and chemical companies. The exchange of process and product technologies was mostly carried out through licensing agreements. The main actors in the chemical market for technologies were firstly the Specialised Engineering Firms (SEFs), although large chemical companies were largely involved in licensing their proprietary technologies.

Before discussing the reasons that pushed large companies to pursue these strategies, and deepening our understanding with the analysis of the Himont case, it is useful to provide some general empirical evidence of technology exchange in chemicals. Thus, the objective of this section is to describe the market for technologies in greater detail, both by comparing different means for transferring technological knowledge, and by taking into consideration country characteristics.[1]

As far as the regional distribution of licensing agreements is concerned, table 1 considered 5,442 licenses that were exchanged in the US, Europe, Japan and Germany. Data are drawn from the *Chem-Intell* database.[2] Four different types of technology suppliers were considered:

a) *top chemical companies* – those ranking in the top 50 positions in terms of number of plants owned and reported in the dataset;
b) *other chemical companies* – those owning more than 5 plants, but not top companies;
c) *Specislised Engineering Firms*;
d) *staff* – the case in which firms developed internally the process technologies used in their plants.

Table 1 shows that SEFs are the most important source of chemical processes technologies in all the developed countries. They own 50.9% of the total market for technology. Half of the transactions are in the US (23.3%), followed by in-house technology development (16.3%). However, when one considers the frequencies of SEFs transactions and in-house technology development conditional upon each receiving country, these shares are very similar. In all the four regions, about 50% of the technologies are supplied by the SEFs, and 40% by the companies' staff. This suggests that, apart from using its own technology expertise, chemical companies often rely on the specialised suppliers of process technologies.

Table 1 – Shares of licensing agreements by type of licensor and region (1980-1997)

	Receiving Country				
Licensor	Germany	UK	Japan	US	Total
Top Chem. Companies*	1.7	1.4	2.7	3.7	9.5
Other Chem. Companies*	0.1	0.2	0.2	0.3	0.8
SEFs	8.9	8.3	10.4	23.3	50.9
Staff	7.4	5.6	9.5	16.3	38.8
Total	18.1	15.5	22.8	43.6	100.0

**Top Chem. Companies*: Companies in the top 50 positions in terms of number of plants; *Other Chem. Companies*: Companies with more than 5 plants, excluded the top 50 companies.
Source: Chem-Intell, 1998.

This phenomenon is further analysed in table 2, which considers the type of companies involved in the vertical linkages. The analysis confirms that SEFs are the principal suppliers of technologies in the chemical sector – they cover the 68.2% of the total market for licensing. This is true for all types of companies with at least one chemical plant. The SEFs license almost 50% of the technologies used by the top chemical firms, 70% of the technological know-how used by the companies with at least 5 chemical plants, and 80% of the technology used by the companies with less than 5 plants. The top chemical companies have the lowest share of technology received from the SEFs, clearly due to their higher technological capabilities developed in-house. This is confirmed by table 2. Not only top chemical companies develop by themselves almost half of their technological know-how, but they also sell these technologies to other chemical companies.

[1] An extensive analysis on this issue can be found in Cesaroni and Mariani (2001).
[2] The *Chem-Intell* database collects information on 36,343 plants built world-wide since 1980. For each plant, a number of detailed information are present: kind of production realised, production capacity, technology used, owner of the plant, contractor which provided the engineering services, licensor, construction year, and so on.

Table 2 – Shares of licensing agreements by type of licensor and licensee (1980-1997)

Licensor	Receiving Company			
	Top Chem. Companies*	Other Chem. Companies*	"Non" Chem. Companies*	Total
Top Chem. Companies*	1.6	6.9	2.7	11.2
Other Chem. Companies*	0.2	0.9	0.4	1.5
SEFs	9.3	39.8	19.1	68.2
Staff	8.6	8.8	1.7	19.1
Total	19.7	56.4	23.9	100.0

**Top Chem. Companies*: Companies in the top 50 positions in terms of number of plants; *Other Chem. Companies*: Companies with more than 5 plants, excluded the top 50 companies; *"Non" Chem. Companies*: Companies with 5 or less than 5 plants.
Source: Chem-Intell, 1998.

The role of SEFs in licensing is further analysed in table 3. Although the SEFs started as an American phenomenon, table 3 shows that other countries are now successfully competing with the US in this field, particularly in Europe and the third-world markets. However, while the US SEFs have a sizable share of the European market, the European SEFs have only a small share of the US market. In particular, table 3 shows that the market share of US SEFs in licensing is about 15%, followed by West Germany with a share of 8.8%. However, if one looks at the share of US licenses in Europe and Japan with respect to the correspondent shares of her competitors, the comparative advantage of US SEFs in licensing is even more apparent.

Table 3 – Market share of SEFs (Shares of Total Number of Plants by Region, 1980-1990).

Nationality of SEFs	Regions				
	USA	West Europe	Japan	Rest of the World	Share of Total World Market
USA	18.0	10.3	6.5	16.9	15.1
West Germany	3.1	11.3	1.0	10.2	8.8
UK	1.2	3.0	2.7	1.4	2.4
Italy	0.1	1.4	0.0	2.2	1.6
France	0.1	0.6	0.0	0.9	0.7
Japan	0.1	0.1	1.5	1.1	0.7

Source: Chemical Age Profile (Arora and Gambardella, 1998).

Finally, in table 4 an estimation of the "value" of the licensing market in chemicals during the period 1990-1997 is shown. Information have been drawn from the *SDC* database.[3]

The values reported in table 4 have been calculated as follows. We first considered the whole SDC database (52,000 transactions), and selected the licensing agreements that disclosed the unit value. We then attributed each license to one of the 5 industrial sectors shown in table 4. For each of these 5 sectors we computed the average value of a license (first column on the

[3] The SDC database (*Securities Data Company*, 1998) and *Chem-Intell* (1998). The SDC database typically reports product licenses. The database is constructed from SEC filings (10-Qs), financial journals, news wire services, proxies and quarterly reports. There are information on about 52,000 inter-firm agreements world-wide in all sectors. For each transaction there are information on the type of agreement (i.e. license, joint R&D, joint manufacturing, etc.), whether the agreement involves a technology transfer, the number of partners involved, the sector, the country and the region of the transaction. Data are available from 1990 to 1997.

left).[4] We then calculated the number of licenses by sector and, based on the estimated mean value per license, we computed the total amount of money involved in the exchange of knowledge in the 5 sectors (first column on the right).

Table 4 – Value and number of licenses by sector (Millions of dollars, 1990-1997)

	Estimated Value per License	**Nr. of Licenses**	**Total Value per Sector**
General Chemicals	104.2	248	25,835.4
Pharmaceuticals	117.4	1,394	163,606.7
Soaps & Cosmetics	3.0	29	87.0
Rubber & Plastics	3.0	41	123.0
Petroleum Refining	6.2	33	203.2
Average	46.7	349	16,298.3

Source: SDC, 1998.

Table 4 shows that the pharmaceutical sector reports the highest number of licensing agreements and the highest value per alliance, and hence moves the largest amount of money. By contrast, in the general chemical sector, licensing agreements tend to be less numerous, although the unit value is rather high. The market for knowledge seems to be relatively less developed in soaps and cosmetics, rubber and plastics and petroleum refining, where both the number and the unit value of agreements are low compared to the other sectors in table 4.

2.1 The changing strategic aptitude of large chemical companies

The empirical evidence reported in the previous section highlighted the active role of both SEFs and large chemical companies in licensing their process technologies. While the behaviour of SEFs has been the result of an increasing division of labour at the industry level, the presence of large companies in the market for technologies is rather a recent event. To be sure, few of them have been active technology licensors for a long time – especially is some branches of the chemical industry, like in polyolefins, and particularly in polyethylene (PE) and polypropylene (PP). Union Carbide and Exxon Chemical, with their Univation Technologies joint venture, Montell, Nova and Borealis are some of these examples. Indeed, forty to fifty percent of new PE capacity is built using technology licensed from third parties (Chemical Week, 1997b).

The interesting point, however, is that more and more chemical companies, also operating in sub-markets different from polyolefins, are approaching this new strategy, and licensing process technology is rapidly emerging as one of the most popular growth strategies in the chemical industry. The examples of Dow, Monsanto, and DuPont, traditionally reluctant to license their proprietary know-how, are rethinking their strategies and are representative of this new strategic approach.

Dow Chemical began its licensing activity in 1995, evaluating all of its 120 manufacturing processes for licensing potential, mainly aiming at contrasting rising R&D costs with a new revenue source. It also recognized the success of such long-time process licensers as Union

[4] In two cases – i.e. soap and cosmetics, and rubber and plastics – we had too few observations (less than 5 licenses). Thus, instead of calculating the mean value, we considered the median value of the whole sample of alliances.

Carbide and BP Chemicals, and the potential of licensing revenues to be less cyclical than commodity businesses. Further, Dow saw opportunities to acquire new technologies by licensing know-how from other companies. The key of this new strategy was an extensive inventory of Dow's existing portfolio to determine what technologies could be of value to other companies and what technologies Dow needed to acquire. This task was promoted by a newly formed licensing group, which also worked closely with Dow's business groups to ensure that potential licensing revenues for each of the processes would exceed a business group's potential loss of monopoly technology position. In the moment in which the licensing group was formed, Dow's goal was to have a portfolio of a half-dozen technologies to be repeatedly licensed, so as to increase its licensing revenues from $10-20 million/year, to $100 million/year by 2000 (Chemical Week, 1997a).

A similar path was covered by **DuPont Specialty Chemicals**, which formed in 1998 a group to license its process technologies, including acrylonitrile, aniline, sulfuric acid, and a range of performance chemicals processes, with the aim of generating $10 million/year in licensing revenues and add 10 licensees/year to its existing listing of about 50. The creation of the new group was the result of a changing behaviour towards technology licensing. In the past, indeed, DuPont carried out licensing only reactively, while the objective of the new group was to open up DuPont's 25 specialty chemicals businesses to licensing, some of which have been available for license for the first time. Indeed, DuPont observed an increasing interest in its acrylo process, especially from Midddle East and Asian producers, where only two technology suppliers were operating. The new licensing group coordinated its activities with the Corporate Technology Transfer Group, which was formed in 1994 to oversee all tech transfer activities (Chemical Week, 1998b).

Similarly, **Eastman Chemical** established in 1998 a technology licensing unit, called Eastman Global Technology Ventures, in order to sell its under-utilised intellectual property portfolio. Indeed, in the view of the company this choice offers potential for non capital-intensive growth and near-term returns. Hence, the company started assessing its portfolio for possible products (Chemical Week, 1998a).

What is behind this increasing interest towards technology licensing shown by the largest chemical producers? The first simple answer is that by both licensing and selling products made by using the same technologies firms can increase the financial return from R&D investments, especially when companies have a share of under-utilised technology assets available for licensing. In this sense, licensing becomes an important growth mechanism for firms. Furthermore, the examples of BP Chemicals and Union Carbide, which have been long-time successful process technology licensors, may have persuaded more and more companies to license, attracted by the prospects of creating more value from existing technologies.[5]

Licensing, however, implies certain risks, mainly because the licensees can become potential future competitors in the final product market. In order to avoid this risk, companies usually

[5] In 1997, Union Carbide and Exxon Chemical have set up a joint venture to sell technology for producing polyethylene (PE). The new joint venture company, **Univation Technologies**, started licensing Carbide's *Unipol* gas-phase process and Exxon's metallocene technology. In the PE licensing business, it held a leading position with roughly 50% of the market (Chemical Week, 1997b). One of the objective of the joint-venture was to offer cutting edge processes and supply catalysts used in the manufacturing of PE for the Asia Pacific region. The joint venture targeted at the Asia-Pacific region because consumption of all types of PE was projected to grow 7-9% annually till 2000. Indeed, at that time, Asian demand for PE was comparable to North America's and surpassed Western Europe's (Business Times Singapore, 1997).

adopt two different solutions. On the one hand, they select for licensing those technologies that are not critical for them. On the other, they keep in-house processes which are a technological step ahead of those licensed. Hence, while they are licensing some process technologies, they are working on the next generation of technology for internal production needs. For example, Monsanto and Nova behaved in such ways, respectively (Chemical Week, 1997b).

It is interesting to note, however, that these two solutions represent only one possible mean to avoid or reduce the risks involved in licensing, and can be considered traditional answers. On the contrary, under certain conditions, licensing out the latest (or the "best") technology becomes the optimal strategic choice as well. The case of Himont which will be discussed in the next sections is one of such examples. The presence of a product demand constantly increasing, the need to set up a standard in the process technology market, and the presence of already existing technology suppliers in the same market pushed Himont to license out aggressively its proprietary technologies.

3. Why is licensing so diffused in chemicals? [6]

The empirical evidence reported in the previous section highlights how diffused are market-based interactions for the exchange of process technologies in chemicals. The willingness of companies to pursue a strategy of active technology licensing has surely increased the size of the market for technology. However, in many cases, the decision to begin licensing has been either a reaction to competitors (or SEFs) already licensing their processes, or an attempt to reduce R&D investments and technology development costs by imitating the behaviour of long-term successful licensors. Their actions represented only an incremental effect on a market already existing and functioning. Hence, the existence of the market for technology in chemicals *has to* stand upon conditions that are different from firms' choices, and that can be considered as pre-existing necessary conditions. Among these, it is possible to consider two aspects:

a) the knowledge base from which innovations are developed, which is generic to several applications, and can abstract from specific contexts;
b) the existence of self-reinforcing characteristics of the market for technology.

As far as the characteristics of the **knowledge base** are concerned, the developments in the scientific understanding in many chemical disciplines and the progress in the instrumentation have caused chemical research to move away from trial-and-error procedures to science-based approaches to industrial research. Scientific discoveries and general principles are the bases to "design" new products and processes.

This argument is related to the presence of tacit or codified knowledge in chemicals. In general terms, the more *general and abstract* is a piece of knowledge, the easier it is to transfer that knowledge to other people and organisations that might use it for different purposes. By contrast, as the *context and firm specificity of knowledge* increases, the more it is difficult and costly to transfer that knowledge (Arora and Gambardella, 1994). In turn, general and abstract knowledge can be more easily transferred, and this allows for a greater division of innovative labour, with some firms or institutions developing more general technologies and others using them for specific applications. This opens up different alternative modes for

[6] The discussion reported in this section is based on Cesaroni and Mariani (2000).

organising the innovative process, and allows firms to pursue different strategies to get access to new technologies, from in-house development to "outsourcing" decisions.

In the case of the chemical sector, may conditions operating in the cognitive environment reduced the degree of tacit and context specific features of knowledge. The concept of the unit operation developed in 1915 and the related emergence of chemical engineering as an academic discipline, the growing importance of petrochemicals after the Second World War, and the increase in the scale and complexity of chemical plants related to the introduction of petrochemicals led to the rise of a new market for engineering and process design services for chemical plants. In particular, the development of chemical engineering as an academic discipline made it easier to separate the process design from the details of the compound being product in the plants – chemical engineering is usually known as the "science of chemical processes". In turn, the codification of process technologies and the rise of specialised technology suppliers led to a vertical division of labour in the chemical-processing sector. Process technology was made into a "commodity" that could be traded due to general-purpose nature of the knowledge exchanged. Put differently, a market for process technology developed because the technology traded was nothing else than general and abstract knowledge that could be applied to different applications and markets.

As the empirical evidence described in the previous section has shown, this market for technological knowledge in the chemical sector was (and is) mainly operated by a large number of small specialised and technology-based firms, the SEFs, which has been an original and persistent feature of the American chemical industry. With a few exceptions, the SEFs did not develop radically new processes. They were good at moving down the learning curve for processes invented by the large oil and chemical companies. And, equally important, they acted as independent licensors on behalf of other firms' technology.

It is also worth noting that the SEFs started as an American phenomenon.[7] This was because the large size of the market has been a crucial factor for the rise of SEFs (Freeman, 1968). By the end of World War II, the world demand of chemical products grew – especially of petrochemicals – and pushed companies to raise the scale of production. The large scale increased the size and complexity of the plants, so that companies often faced a technological capability constraint, and demanded the intervention of external engineering specialists.

The special features of the knowledge base, and the consequent diffusion of specialised technology suppliers, were only the first condition that enhanced the diffusion of market-based exchanges in chemicals. The competitive interaction between SEFs and incumbent chemical producers was the second. Indeed, the existence of the SEFs, whose business is to sell process technologies and to appropriate rents from innovations, encouraged other chemical and oil firms to license their own technologies for making profits out of them, in a way of inducing a **self-reinforcing mechanism** that allowed the market for technology in the chemicals to persist over time.

The traditional and managerial literature (among others, see Teece, 1988) holds that companies can gain value from their innovations mainly by exploiting them in-house. There are many reasons why technology licensing is considered an undesirable strategy. Apart from the existence of transaction costs problems, and of cognitive constraints, the main reason is that by licensing, firms create new competitors in the downstream product market, hence

[7] According to Freeman (1968), 50% of the total value of engineering contracts world-wide in 1960-66 were done by American SEFs.

reducing their profits in the product market and dissipating rents. Many companies' CEOs have similar concerns regarding technology licensing (Chemical Week, 1997b). In other words, firms incur in the *rent dissipation effect*, which consists in the erosion of profits due to another firm competing in the downstream market. But licensing also provides revenues from the sale of technologies (the *revenue effect*), in the form of licensing payments. Hence, the question is under what conditions the revenue effect is greater than the rent dissipation effect, so that of inducing licensing (Arora and Fosfuri, 1999).

The answer to this question mainly depends on the degree of competition – whether the company is a monopolist or operates in a competitive market – that the company faces in the product market. In the case of the chemical industry, specialised technology licensors that lack the downstream complementary assets in production and commercialisation sell more licenses – in this case, the rent dissipation effect is zero. However, in the presence of such licensors, downstream producers may be induced to license their technologies as well. In fact, given that the licensing activity of others create new competitors in any case, and hence reduces the capability to gain profits in the product market, the downstream producers may well have incentives in competing in the market for technologies, by selling their proprietary technologies. This is what exactly happened in the chemical sector, and the case of Himont strongly support this argument.

The SEFs acted as independent technology suppliers, by selling process technologies to potential entrants in the product markets, and in turn this behaviour induced downstream chemical companies to become technology suppliers as well. Moreover, licensing by rivals in the downstream markets increased the propensity of other chemical companies to license their proprietary technologies as well. In this sense, licensing strategies tend to strengthen over time (i.e., there are self-reinforcing mechanisms). As a matter of fact, once established, the market for technology tends to persist over time. Indeed, in the chemical sector the market for process technologies has been a constant feature over the last forty years. Even today, Arora and Fosfuri (2000), using data on worldwide technology licensing during the 1980s, find that in those sub-sectors where firms without downstream assets license more, large chemical producers themselves tend to license more.

4. Demand, standards and antitrust in the case of Himont [8]

4.1 Background

The case of Himont is part of the story of the plastic materials and especially polypropylene (PP). Advances in polyethylene and polypropylene in the 1950s helped establish these useful plastics as universal materials. Although ICI and DuPont were already producing high-pressure polyethylene for applications such as electric wire insulation, Germany's Karl Ziegler isolated a low-pressure crystalline polyethylene that seemed promising. Ziegler had begun work on ethylene polymerisation in the 1930s at the Kaiser Wilhelm Institute for Coal Research (in East Germany), and then carried the work to completion on organometallic catalysis of polyethylene at the Max Planck Institute (in West Germany) after the war. Hercules started up the first low-pressure crystalline polyethylene unit in the U.S. in 1957 based on a license from Ziegler's patents; Koppers and Union Carbide soon followed (C&EN,1998).

[8] Information on Himont have been drawn from a face-to-face interview with Mr. Roberto Rettani, who has been one of the company's former CEO.

Against this economic and technological background, Himont was created in 1983 as a joint-venture between the Italian Montedison and the American chemical group Hercules, both with a share of 50%. The venture then had 2.5 billion lb of annual capacity and $750 million in sales. The reasons for the creation of the joint-venture lay in both the financial weakness and the technological strength of Montedison. Indeed, in that period, Montedison had developed an innovative technology aimed at the polymerisation of polypropylene, called *Sheripol*, based on an improvement of the Ziegler-Natta stereospecific catalysis – Karl Ziegler and Giulio Natta shared the 1963 Nobel Prize in Chemistry for that discover.[9]

The *Spheripol* liquid-phase process had enormous advantages compared to existing (and traditional) process technologies for PP. First, the *stereospecific feature of the catalyst* allowed a greater performance of the production plant and a greater control over the physical structure of the polymer, which directly influenced its physical behaviour and properties. Second, the *compactness of the catalyst*. By definition, a gas-phase process is necessarily larger than a liquid-phase process, because a fluid requires a smaller space to be stored and handled than a gas. In turn, third, the greater compactness of a gas-phase plant implied *lower investments and plant development costs*.

Furthermore, by using different types of catalysts – a second know-how of Montedison – it was possible to obtain different types of polymers. This characteristic induced a great flexibility to the plant, allowing the operator to define different types of PP to be used in different specific applications. For example, by changing the physical structure of the polymer it was possible to obtain a range of different products, from films for the food industry to gel membranes, from car bumpers to upholstery for the car industry, to fibres for fabric to be used in the textile industry. Simply by defining the right molecular structure of the polymer it was so possible to influence its physical properties (softness, flexibility, toughness or rigidity).

Although Montedison had developed and controlled this technology, at the beginning of 1980s it suffered of a strong financial crisis. It had not the financial capability neither to promote the industrial development of the technology, nor to build new plants, nor to reconverting its existing plants to the new technology. In such a situation, the alliance with Hercules was an optimal solution. Hercules, indeed, had already a diffuse presence in North America and also a quite large presence in the Far East, regions where Montedison had no presence at all. And the possibility to operate in a global market was key to effectively exploit the new technology. On the other hand, Hercules had plants using older technologies and was not investing in their development because was trying to diversify in different segments. In addition to the geographical complementarity, the strength of Hercules was in downstream markets, where it had a large market share in the production of PP fibres and films.

Because of these complementarities, Montedison and Hercules decided the creation of the joint-venture aiming at the production of PP by using the *Spheripol* process, and at the licensing of the same technology to third parties. During the first period, the new venture performed quite well, also by taking advantage of the growth of the market of plastic materials, which on the contrary suffered of a great crisis some years before. As a matter of

[9] When professor Giulio Natta, working at the Milan Polytechnic Institute and financed largely by the Italian chemical producer Montecatini, scribbled the note "Made polypropylene" in his diary on March 11th 1954, he probably did not suspect that he had laid the foundation for what was to become the world's most versatile family of synthetic materials. In the four decades that followed, polyolefin process and catalyst technology made enormous advances. (This anecdote is quoted in the Montell web-site: http://www.montell.com).

fact, in two-three years following the creation of the joint-venture, Himont was able to build all the planned plants, to reconvert all the existing plants of Hercules, to reconvert the existing plants of Montedison, mainly by using internal financial resources.

Obviously, the success of Himont due to the new technology stimulated the reaction of competing companies – among which Fina, Shell, Atochem, DSM in Europe; Shell, Exxon, Kodak, US Stell, Union Carbide in the US – which used different technologies. Many of them were primarily large diversified petrochemical companies, which controlled and optimised the product flow from the cracker to the final products, and which produced PP by using very different technologies. Among the set of competitors there was also Union Cabide – whose aggressive licensing strategy has been recalled in the first section – with its *Unipol* gas-phase technology.

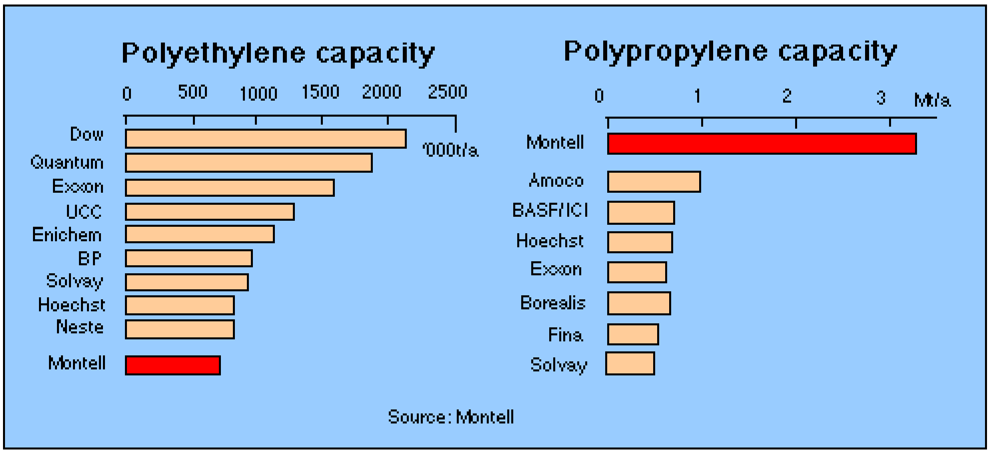
In 1987, Himont's sales exceeded $981 million and its annual capacity approached 3 billion lb (C&EN, 1998). In the same year, the partners decided to sell a 22% interest in Himont to the public (at the New York Stock Exchange), and later that year Hercules sold its remaining interest to Montedison. By 1990, Himont reached annual sales nearing $2 billion and polypropylene capacity of almost 4 billion lb. During the same year, Montedison decided to buy the outstanding public shares of Himont, so as to maintain the control over the 100% of the capital. Why this choice?

Unfortunately, the answer to this question is strictly linked with the economic, social and political situation of the Italian chemical industry in that period. The two Italian chemical giants (ENI and Montedison) had just merged in Enimont, but leaving Himont (and other few companies such as Ausimont) outside of the new company. However, when the former CEO of Montedison, Mr. Gardini, tried to acquire the control of the State-owned part of the company, his intention was to use Himont as possible "exchange currency" against the State. Corruption and bad political behaviour made the rest. Enimont was split up again into the two original companies (ENI and Montedison), the Ferruzzi family (owner of Montedison) left, and Montedison started its financial crisis.

In order to solve financial problems, Montedison was forced to sell Farmitalia Carlo Erba to Pharmacia, and at the same time it tried to find an agreement with Shell Chemical in order to sell Himont. Instead of a complete selling, the management of Himont tried to create a joint-venture with Shell, where Montedison had at least a part of the control over the new company. In the view of Montedison's management, the joint-venture had to be only a temporary solution, waiting for a restructuring of the company.

The agreement with Shell was a also a positive solution to the changes in the PP market. First, Shell was strong in northern Europe and Australia, which complemented Montedison in southern Europe, the US and the Far East. Shell also contributed feedstocks from its cracker in southern France. This would have made Montell the only fully global PP player. Second, the big customers (large car producers) were starting to reduce the number of PP suppliers and to establish closer links with a limited number of them. Shell, however, was used to pay few attention to customers' needs, and to compete mainly on lower prices (and large quantities). Himont, on the contrary, because of its existing licensing strategy, was much more customer oriented, so that Shell was going to "learn" a new business model by merging with Himont. Furthermore, the agreement aimed at improving the technological knowledge of the two companies as well, especially with regards to catalyses in which both companies had relevant technological competencies.

Figure 2 – PP and PE production capacities (1996)



Source: C&IM, 1996.

After two/three years of contracting, in 1995, Montedison merged Himont into a joint venture with Shell Chemical's polypropylene business to form Montell, creating a producer with more than $3 billion in annual sales and more than 7 billion lb of polypropylene capacity. One year later, in 1996, Shell worked out an agreement to buy out Montedison for $2 billion (C&EN, 1998). At that period, Montell was the world's largest producer of polypropylene by a huge margin, producing almost three times as much as its nearest competitor, Amoco (see figure 2). Its 21 PP sites, in 14 countries on five continents, were producing almost 3.1 Mt of the polymer every year. The company was formed with about 7,500 employees, including 800 in R&D and 750 in marketing (C&IM, 1996).

4.2 Motivations for technology licensing

One of the most interesting aspects of the story of Himont is that, during the different phases of its life, the company has never changed its licensing strategy, neither when the competitive environment, nor when PP market demand has changed. As it will be better explored in the following, one of the main reason of this choice was the fact that becoming technology leader was a valuable strategy also for customers. Indeed, when a technology standard stands out among others, the customer reduces the possible risks of second sourcing, and has a greater guarantee of product's quality and availability. This happens indifferently when it buys from the technology leader or from its licensees.

As a matter of fact, Himont has been constantly active on technology licensing. Montedison started licensing before the formation of Himont. During the 1970s, it was collaborating with Mitsui (Japan) for improving the Ziegler-Natta catalysis. Then Mitsui developed a production process competing with Montedison's *Spheripol*, but the research collaboration between the two companies continued in the field of catalysis. The beginning of the licensing activity by Montedison was primarily an historical accident. When developed, Montedison had not the financial capability to promote the industrialisation of the *Spheripol* process, and licensing was the only way to gain returns from R&D investments. This suggests that, because of the lack of downstream complementary assets in production, Montedison acted and thought at the beginning as a real technology supplier of today. Notice that the alternative viewpoint (i.e. if markets for technology did not exist) was to not develop the technology, because Montedison could not exploit it internally by producing the product downstream

Table 5 – Major PP producers by number of plants (1980-1997)

Rank	Company	N. of plants	Rank	Company	N. of plants
1	Himont	14	11	China Techimport	5
2	Shell	12	12	Chisso	5
3	Amoco Chemicals	11	13	Mitsui Petrochemical	5
4	Hoechst	9	14	Montedison	5
5	Mobil	9	15	Repsol Quimica	5
6	Techmashimport	8	16	Solvay	5
7	BASF	6	17	Sumitomo	5
8	Exxon Chemical	6	18	DSM	4
9	Hercules	6	19	Huntsman Chemical	4
10	Borealis	5	20	Indian Petrochemicals	4

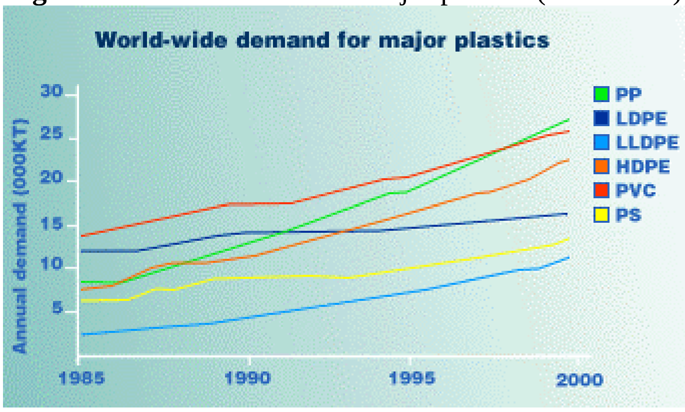
Source: Chem-Intell, 1998

But licensing was not so easy at that time, because the technology was not completely tested, and the only existing plant using the new *Spheripol* process was a pilot plant built by Montedison at Ferrara. Notice, however, that Montedison before, and Himont later, were mainly a manufacturing company. Their primarily business was selling chemical and plastic materials (e.g., PP and PE), and not technology licensing (see table 5). Hence, licensing was only a *further* way of increasing returns. Also note that because the company had experience in plant this probably meant that they developed the technology because they thought that they were going market the product in any case. In this sense, Montedison behaved probably different from today's technology suppliers, which increasingly start by thinking that will eventually sell the technology and not the product.

In Himont's decision of continuing the licensing activity of Montedison, three elements have been key: a) the increasing demand of PP all over the world during the 1980s and 1990s; b) the licensing activity of Himont's competitors; and c) the desire of Himont of setting-up a global standard in PP materials. As far as the role of PP demand is concerned, one of the crucial features of plastic polyolefins is the way they were progressively matching and exceeding the performance of a growing number of other polymers and synthetic materials, because of their capability of adapting at different working conditions. This dramatic increase in versatility is reflected in the rapid penetration of this plastic materials. As a matter of fact, polypropylene demand has grown by an average of 9.7% a year over the last fifteen years (see figure 3).

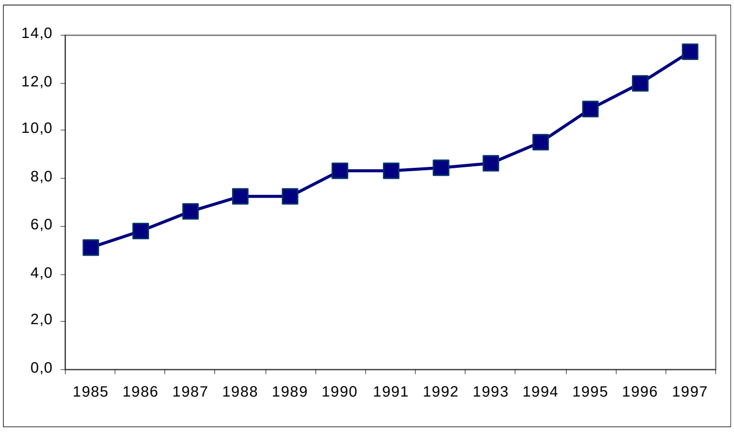
In turn, the increase in PP demand has resulted in a corresponding increase in the number of producers, and of overall PP production (see figure 4). Most of the producers, however, had not the technological capability to develop their own process technology, and considered outsourcing as one interesting possibility. Thus, the increasing demand of polypropylene stimulated both the demand of PP production technologies, that were exchanged by means of licensing agreements, and the entry of new licensors in the market for technology. In the first half of 1980s, the demand of PP technology licenses has grown constantly, especially in Europe and the US, but suddenly it expanded in other regions, Far East and Japan included – e.g., Himont has been the major technology licensor in China, where it provided the process technology to more than 17 PP plants.

Figure 3 – World demand for major plastics (1985-2000)



Source: http://www.montell.com

Figure 4 – World production of polypropylene (millions of lb)



Note: data include Canada from 1995. *Source*: C&EN (1996, 1997, 1998)

Hence, one of the consequences of the increase in PP demand, was the increase of competition in the market for technology. Although Himont remained for long the leading technology supplier, the number of competitors constantly increased during the 1980s and 1990s (table 6). Probably in that period, Himont's technology had the highest performance and characteristics, but other new technologies were rapidly emerging. Union Carbide and BASF, for example, became aggressive Himont's competitors in the PP business.

This situation appears to be consistent with Arora and Fosfuri's theoretical model, by which licensing becomes the optimal strategy when the supplier is not a monopolist in the downstream product market, or even when the company is a monopolist in the product market but it is in the presence of a potential technology licensor (Arora and Fosfuri, 1999). The *revenue effect* given by licensing is greater in this case than the *rent dissipation effect* given by the increased competition from the additional licensee. In the view of Himont's management, the possibility of creating additional competitors in the PP market was perceived indeed as a threat. As exposed above, Himont was primarily a manufacturing company whose largest share of turnover came from selling polypropylene. In this sense, a product unit sold directly to the final market was obviously more convenient than a share of licensee's earnings. However, in the presence of other potential licensors – such as Carbide, Shell or BASF –, Himont would have occurred in any case in a reduction of profit margins due to increased competition in the final market, because new producers would have eventually entered by using technologies of Himont's competitors. The presence of a potential licensor (Shell, BASF, Carbide, etc.) created incentives to license because the other licensor would have licensed in any case. In this situation, licensing represented on the contrary the possibility of capturing additional value from R&D investments.

Table 6 – Major PP technology suppliers by number of plants operated (1980-1997)

Rank	Licensor	N. of plants
1	Himont	64
2	Union Carbide	32
3	Shell	26
4	BASF	25
5	Mitsui Petrochemical	23
6	Montedison	17
7	Amoco	16
8	Hercules	10
9	Hoechst	9
10	Mitsubishi Petrochemical	8

Source: Chem-Intell, 1998.

By licensing, however, Himont was able to assure two further ways of gaining profits. The first is related to the linkages with the Montedison industrial group. As will be better explored in the next sections, the purchase of a technology license ended up with the deliver of the projects, the technical notes and all the relevant information to be used by the engineering firm in the plant construction. Then, the licensee had greater flexibility concerning which engineering firm to use. However, in most cases, the licensees of Himont's PP technology were using the engineering firm of Montedison group (*Tecnimont* – see table 7), which had acquired expertise and know-how in that technology. This assured the licensee that the plant was perfectly operating. At the same time, in order to produce polypropylene, a plant requires both the feedstock of propylene, and a specific catalyst which enters in the chemical reaction in shares of 2-3%. As in the case of the engineering firm, licensees had no contractual obligation of acquiring the catalyst from Himont, and were free of asking to different suppliers. However, Himont's catalyst was perfectly suited for that technology and assured the highest performance, so that most licensees chose Himont for the catalyst supply. Notice also that a catalyst is a speciality chemical product, whose price-to-quantity ratio is especially high (it costs about $350/kilo at current prices). Hence, the total earnings from a technology license were relevantly higher than the licensing fees and royalties, if indirect earnings are also included.

Table 7 – Major PP engineering firms by number of plants built (1980-1997)

Rank	Engineering Firm	N. of plants
1	Tecnimont	48
2	Mitsui Engineering & Shipbuilding	13
3	Uhde	10
4	Fluor Daniel	10
5	Lurgi	8
6	Foster Wheeler	5
7	Technip	5

Source: Chem-Intell, 1998.

Finally, the third element that was key in Himont's decision to license its proprietary technology was the attempt to create a technology standard in the market of plastics. Although by licensing new competitors in the downstream product market were created, usually the final customer of PP was used to acquire polypropylene from two or three different suppliers – i.e., they used second sources of PP. This was especially true regarding the big car producers. However, these customers certainly preferred to have different suppliers but with very similar materials (PP), in order to assure similar characteristics to end-products and similar manufacturing possibilities. In this sense, they preferred to buy PP from Himont and from Himont's licensees. Indirectly, the presence of PP suppliers using the same technology of Himont, instead of increasing the level of competition in the product market, was a way of creating stricter and longer relationships with the final customers. In the short-term they probably reduced Himont's market share in plastics, but allowed Himont to maintain its (reduced) market share in the long-run. Without the possibility of creating a product standard, probably Himont would have been threatened by other suppliers using technologies of Himont's competitors in the market for technology. In this sense, Himont's behaviour is consistent with the predictions of Khazam and Mowery (1993) related to the creation of a technology standard in the computer industry.

4.3 Management of technology transfer

The case of Himont also appears to be interesting because of the practices of technology transfer that have been used, which represent a typical example of technology transaction in chemicals. The definition of price, payment methods, knowledge disclosure, and prospective further developments are all elements that have to be considered in a licensing agreement. Related to these topics, Himont created an internal group composed of about 15 people with the purpose of completing the different steps of the transaction.

Usually Himont did not spend much time and large amount of resources in "marketing" its technology. Any potential licensee was used to ask conditions to two or three different suppliers. As mentioned above, Himont's *Spheripol* process had the best features compared to alternative technologies for PP manufacturing existing at that time, so that usually demand of licenses exceeded Himont's supply capabilities. Once contacted, Himont's licensing group gave some general information related to the technology and the licensing agreement, without entering into the very (protected) details of the technology. If the buyer accepted Himont's offer, then the two entered in the definition of contract details, where Himont was used to allow a great flexibility in order to satisfy customer's needs.

One of the details to be defined was the method of payment. Standard licensing contracts usually included a fixed amount (*down-payment*) and a variable quantity as a percentage of licensee's turnover or profits (*running royalties*). This arrangement clearly represents a partial solution to problems of information asymmetry in knowledge, and hence a possible solution to Arrow's information paradox (Arrow, 1962). The proportion between the two elements was not fixed. Some Himont's licensees (or licensees coming from some specific countries) preferred higher amounts of down-payments and lower running royalties, while others preferred the opposite. Typically, however, the first down-payment had to be paid at the contract sign, to which other two/three payments followed before the plant was completely built and operating – it took about two years. Payments were due at specific milestones: the contract sign, the first and the second technology package disclosure, and finally, the completion of plant design. This represented the final step of a licensing contract, by which the licensor offered to the licensee its (patented and tacit) technological know-how and a plant design to be used by an engineering company in order to build the plant. After the deliver of the plant design, the licensing contract was completed and the licensee was free to ask any engineering company to build the plant. As discussed above, however, in most cases licensees preferred to use the engineering firm related to Montedison (Tecnimont), in order to have the highest guarantee of functionality.

The amount of royalties strictly depended upon the amount of down-payments that the licensee had previously to pay. In any case, a *paid up volume* was usually defined, in terms of cumulative amount of production. After that amount was reached, the plant was considered completely paid. As an explicative example, the initial value of the (cumulative) down-payment was on average of about \$10/20 millions, while the royalties were usually defined at about 3% of annual turnover. The total price of the plant usually depended upon its size (small or large), and its functionality (production of a single polymer, of co-polymer, of random co-polymer).

The license price included the use of Himont's patents. By acquiring the license, the licensee acquired the right to develop the technology as well, thus avoiding the risk of patent infringement. Similarly to the idea of Arora (1995 and 1996), it was the control over the codified part of the technology to prevent an opportunistic use of disclosed technological know-how. Indeed, the characteristics of the technology (and especially the properties of the polymer produced) were such that it was easy for Himont to understand which technology and which catalyst had been used, so that Himont could easily discover any patent infringement. In turn, this situation lowered the propensity of patent infringements, and the possibility to further use Himont's technological information disclosed before the sign of the contract and obtained even if the contract eventually was not signed.

The interesting of license agreements, however, was the fact that in many cases they included a term of *reciprocal continuous know-how*, by which both the licensor and the licensee had to provide further technological developments each other. In this sense, any licensing contract partly included a co-development agreement. This solution is quite typical in licensing, and is known as *grant-back* (Tidd *et al.*, 1997). Usually, Himont's licensees invested in the optimisation and customisation of Himont's technology, especially when they were using that technology for a long time. These developments remained within the same technological trajectory of the original technology – they were incremental developments – and it never happened that a licensee developed a radical and competing new technology, by improving Himont's *Spheripol* process. In this sense, licensing agreements never included the risk of creating new technological competitors.

While licensing agreements usually included a term of co-development, the case of cross-licensing was different. In other industries – e.g., electronics and semiconductors (Grindley and Teece, 1997) –, cross-licensing is used by firms as an *ex-ante* solution in order to have "freedom-to-manufacture" and "design freedom" by starting from other's knowledge base. Cross-licensing agreements in chemicals were mainly the *ex-post* result of court trials in the case of patent infringements. However, the reasons for cross-licensing was mainly the same, with the only difference that in semiconductors today people had more experience, and hence they anticipated the possibility of incurring in costly trials and resolved everything ex-ante. Indeed, instead of spending time and money in order to fully understand who was violating other's IP rights, and to assess the amount of corresponding damages, court trials usually ended up with a decision of reciprocal patent disclosure and use. Many chemical processes developed during the 1980s and 1990s were the direct result of patents developed up to 30 years before. During the trials, it was hence difficult to correctly reconstruct the whole patent family and the related IP rights, so that cross-licensing usually became the easier (and less costly) solution. Its purpose, however, was mainly to save time and resources, and not to ease the innovative process.

For this reason, Himont did not developed specific competencies and devoted organisational resources to the management of cross-licensing. In the case of the electronic industry, largest firms have developed specific strategies and related managerial procedures of *Intellectual Capital Management*, which are used in order both to create a patent portfolio valuable in cross-licensing agreements, to assess the values of internal and other's patent portfolio, to define the sectors in which investing the major R&D efforts, and to manage the cross-licensing transaction (Grindley and Teece, 1997). On the contrary, in the case of chemicals, licensing agreements have the main purpose of transferring technological know-how and cross-licensing represents only a "defensive" answer to others' patent infringements. Hence, technology managers are mainly involved in maximising the transfer of technology and less in maximising the value of cross-licensing agreements. The case of Himont clearly responded to this latter view.

4.4 Policy implications: Antitrust

The merger between Himont and Shell was strongly opposed by the European Commission and the US Federal Trade Commission because against the antitrust laws. In order to fully understand the problem, it is useful to consider two events. First, Himont's *Spheripol* and Shell-Carbide's *Unipol* processes were the two top competing technologies for making PP. Almost three-quarters of the world's PP supply was made by using one or other of these two processes (C&IN, 1996). Second, during the long story of the Ziegler-Natta catalysis (starting at the end of the 1950s), Himont has strongly protected its technology with patents. Because of the importance of the technology, however, it was not improbable and infrequent that others were violating Himont's IP rights (patent infringement), and Himont usually reacted by suing them. Instead of spending time and money in trials, in many cases the two parts were ending up with an agreement of (partial) patent disclosure and cross-licensing. For example, this was the case with Monsanto and Goodyear. As a matter of fact, because of the long history of patent infringements and cross-licensing agreements, Himont (Montedison) had created a complex network of technological relationships with different companies.

These two situations were extremely important in the view of regulatory authorities. Probably for the first time since the definition of antitrust laws, the two authorities were opposing to Himont and Shell not for the formation of a monopoly in the plastics market, but in the market for plastic technologies – mainly PP and PE. Indeed, because of the network of patent linkages that Himont had created with other companies, and the fact that Himont and Shell had the leading PP process technologies, the two companies could *de facto* control the whole market for technology and any further technological development. Obviously Union Carbide strongly supported the regulatory authorities. With the merge between Himont and Shell, Carbide was going to loose its technological partner, and its competencies on catalysts – in the partnership Shell-Carbide, the former provided know-how on catalysts, and the latter on the process technology. And this situation was clearly a relevant threat for its licensing business.

Hence, the regulatory authorities allowed the formation of the new joint-venture, subject to a set of conditions (C&IN, 1996). First, The US Federal Trade Commission (FTC) forced Shell's US division, Shell Oil, to spin-off its PP businesses, including its share of *Unipol*, into a separate company (temporarily known as *Polyco*), to be "held separate" from the rest of the firm and eventually sold. Montell had no influence over this company. Second, the European Commission and FTC ruled that Montell shouldn't be involved in granting *Spheripol* licenses either. Montedison created another subsidiary, called *Technipol*, to handle the licensing business. Hence Montell had to supply Spheripol – both the know-how and the catalysts – to Technipol for a fee. Technipol could sell the licenses and catalysts to its clients, and had to pay some of the money back to Montell. Third, Technipol could be integrated back to Montell only when Shell Oil sold Polyco, and Carbide was provided with the technological know-how needed to become a supplier of the "technology package" – catalysts, process and know-how.

Clearly these conditions were especially stringent to Shell. The objective of the formation of Montell with Montedison was to obtain access to Montedison's *Spheripol* technology and its developments – Montedison was developing the new *Catalloy* technology at that moment. But with Technipol left outside the new company, Montell brought no value to Shell. Thus, Shell tried to satisfy rapidly the conditions posed by the two regulatory agencies. Montedison was particularly interested in the new joint-venture as well. Nevertheless, contrarily to Shell, the temporary solution imposed by the authorities was not too costly to Montedison, which could continue licensing out its technologies and earn profits. Rather, because of the financial situation in which it was at that time (which represented the main reason for the creation of the new venture), Montedison licensed aggressively during that period. Indeed, the regulatory authorities required Technipol to complete a periodic report of the activities, and it was particularly easy to demonstrate that the licensing business was not interrupted waiting for the conditions to be satisfied.

As a matter of fact, no more than two years later the antitrust decision, all the conditions were satisfied, and Montell could operate completely. Union Carbide obtained access to Shell technology and became an important competitor to Montell, although Montell remained the leading PP supplier and producer (see figure 2). In the meanwhile, new technologies for the production of PP were emerging (i.e., the *metallocene* technology), and new important suppliers entered the market for technology (e.g. BP, Exxon, Mitsui), hence contrasting Montell and Carbide leadership positions. To be sure, the "old" stereospecific technologies – i.e. *Sheripol*, *Unipol*, and *Catalloy* – remained important especially in the emerging countries of Far East, where downstream manufacturing companies did not need the enhanced properties of polypropylene obtained with the new technologies.[10] In sum, the regulatory authorities' intervention has been probably less severe than expected, because the emergence of new technological trajectories would have eventually broken the Shell-Montedison monopoly in the market for technology, by allowing new actors to enter, and by increasing the level of competition. The authorities' decisions have only anticipated the results of technological progress.[11]

[10] In this sense, Himont's licensing activity at that time was mainly consistent with the traditional theoretical view of leaders licensing the "old" technologies in order to earn the further, additional value from R&D investments.

[11] This story suggests that sometimes there is excessive policy preoccupations when markets can in fact solve the problem. A similar story can be found in the case of patent protection (Mergers and Nelson, 1994).

5. Conclusions

Technology transfer through licensing agreements has been a common feature of the chemical industry since the development of petrochemicals in the 1950s. The worldwide increasing demand of chemical products at that time, and the strong science base of the industry due to developments in chemical engineering and chemical science (i.e. polymer chemistry), were the major forces that allowed a division of labour at the industry level between specialised technology suppliers (SEFs) and downstream chemical companies. Technology exchange between the two was mainly conducted by means of licensing agreements.

The case of Himont can be placed in this framework of international transfer of chemical process technologies. To be sure, however, Himont was not exactly a specialised engineering company. Its main business was selling plastic products (mainly polypropylene – PP), and it was only for some "historical accidents" that it started to license out its proprietary (and in some sense revolutionary) process technology for PP manufacturing. Although motivated by historical internal reasons, Himont's licensing behaviour was subject to the same conditions that induced many chemical companies to enter the market for process technology – typically operated only by the SEFs – and offer their technological know-how. It is commonly recognised that it was the presence of SEFs that, by creating new competitors in the product market and hence increasing the *rent dissipation effect*, induced large chemical companies to license out their technologies, in order to increase the *revenue effect* coming from technology licensing (Arora and Fosfuri, 1999). As a matter of fact, large chemical firms are the second largest technology suppliers after SEFs.

The characteristics of the knowledge base in chemicals eased the process of codification. In turn, the high degree of codification lowered the costs of technology transfer, because it required fewer face-to-face interactions necessary to transfer tacit know-how, and allowed technology suppliers to reach larger markets – i.e. a higher number of customers. This situation strongly influenced firms' strategies for technology exploitation. Instead of long and costly face-to-face interactions, which are usually required in other industries (e.g., machinery) and which sometimes end up with the transfer of technicians and engineers, the higher codification of technological knowledge make it easier to transfer technology by means of market-based interactions (such as licensing agreements).

If this picture characterises the chemical industry in general, the case of Himont appears particularly relevant because it represents a clear example of determinants and implications of technology licensing. Himont's decision to start and continue licensing its new *Spheripol* process technology provided a partial verification of various theories related to technology licensing. The role of downstream complementary assets in production, the role of existing and competing technology suppliers, the role of competition both in the technology and in the product market, the role of market demand, and the role of technology standards were all elements that entered into play, and that were important in shaping Himont's strategy. In this sense, Himont seemed to behave according to theory's predictions. However, while some of them acted as sparking condition – see, for instance, the lack of complementary assets in production – the other acted as reinforcing mechanisms which made profitable to Himont to keep on licensing. Among these, the presence of existing technology suppliers creating new competitors in the product market is probably the most important. And this might suggest that markets for technology once developed create endogenous growing mechanisms.

Acknowledgments

I would like to thank Alfonso Gambardella for helpful comments and suggestions on an earlier draft, and Myriam Mariani and Andrea Piccaluga for continuous discussions on topics related to this work. I am indebt to Roberto Rettani for the interview he gave, and the story of Himont that he told me. The usual disclaimer applies.

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