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# Towards a Characterisation of Assets And Knowledge Created in Technological Agreements: Some evidence from the Automobile-robotics sector.

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# TOWARDS A CHARACTERISATION OF ASSETS AND KNOWLEDGE CREATED
# IN TECHNOLOGICAL AGREEMENTS:

**Some evidence from the automobile-robotics sector[1].**

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## Abstract

This paper tries to bring new insights on the dynamics of inter-firm by focusing on cognitive and organisational dimensions. We consider the knowledge bases created inside the agreement and the characteristics of such knowledge bases (such as tacitness, level of generality, degree of centralisation...). The nature of assets for supporting this creation is also essential for the redeployability of knowledge created. We began by a brief review of some problems encountered by transactions cost economics and present some case studies of agreements between firms in the automobile and robotics sector. After having presented a taxonomy of knowledge and assets involved in such agreements, we bring some new discussion on the exploration/exploitation's dilemma. We argue finally that our taxonomy may be fruitful for a better understanding of the dynamic of firm boudaries by trying to go deeper into the "black box" of agreements.

## Keywords

Inter-firm relations, automobile industry, technological agreements

## JEL Classification

D23, O32, L62

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## Contents

## Preface

We are happy to integrate international scholars in the DRUID network and to publish their contributions in the DRUID working paper series. This is especially so when papers analyze phenomena that are at the core of research programme of DRUID.

A common concern for the programme as a whole is the relationship between knowledge creation and economic development. Learning is regarded as a process that is fundamental for the performance of firms, networks and national systems of innovation. To better understand what is learnt, how and by whom is fundamental for making progress in this respect. This paper by Natalie Lazaric and Luigi Marengo makes an important contribution in this respect. The focus is on learning in connection with technology agreements between firms from respectively the automobile sector and the robotics sector.

Distinctions are made between different kinds of knowledge in terms of degree of codification, generality and centrality and it is shown that these factors have an impact on how and to what degree learning takes place. The paper also demonstrates the limits of transaction cost analysis when it comes to explain technological agreements.

We hope to be able to bring more contributions of this kind where the analysis of learning and knowledge is concrete and empirically based. A key to make economics more relevant is to develop a better understanding of the economics of knowledge-creation and of the learning economy.

Bengt-Åke Lundvall

## 1. Introduction

The purpose of this paper is to attempt an analysis of the cognitive and organisational dynamics of inter-firm technological agreements. One of the neglected dimensions in transactions cost economics is the transfer of knowledge and mutual learning in situations not necessarily characterised by a high degree of opportunism. This conflictual/political dimension is not ignored, but we deliberately choose to focus our attention on the cognitive aspects of the agreements. Incentive and conflict reducing mechanisms cannot on their own explain the existence and dynamics of such agreements and, especially, the creation of competencies in the long run (Chandler, 1992, Dosi, Teece and Winter, 1992).

Transactions Cost Economics focuses on the production of specific assets without considering their underlying knowledge bases. According to us, the nature and characteristics of such knowledge bases (such as the level of tacitness, level of generality, degree of centralisation, etc.) drive the learning dynamics as well as the nature and characteristics of technological, relational and organisational assets. The nature of assets and of the knowledge supporting them is essential for their potential redeployability. Indeed, technological knowledge characterised by a high degree of specificity may be confined to an agreement and hardly be redeployable, thus reducing the combinative capacities of the firm. Such knowledge can thus push the firm into a competency trap, jeopardising its capacity to solve general problems.

After a brief review of some problems encountered by transactions cost economics in accounting for the origin and dynamics of technological agreements, we will present some case studies of agreements between firms in the automobile and robotic sectors. This will lead us to present a taxonomy of the assets and knowledge bases involved in such agreements and to discuss the links between them. Finally we draw some conclusions.

## 2. Dynamics of agreements and production of knowledge: some open questions

The aim of our contribution is to try to offer an alternative perspective from transactions cost economics (TCE) by focusing on the way problem solving and competence gaps, push for the association of dissimilar activities. This point is important for explaining the stability and evolution of the T form - "temporary forms" according to Williamson's terminology (Williamson, 1995). According to us, the TCE perspective misses two important points for the correct understanding of inter-firms relations. As underlined by Brousseau (1996) and Lazaric and Wolff (1996), transactions cost theory falls short of accounting for institutional dynamics, as its perspective is a comparatively static one. Organisational forms are not really examined in their evolution and historical development but compared under the hypothesis that static efficiency properties are sufficient to explain their selection.

According to us this theoretical background, though indeed very relevant, is not sufficient for the analysis of path-dependent processes of organisational adaptation. The very idea of selecting the most efficient organisational form is rather ambiguous, for on the one hand boundedly rational agents can hardly be capable of selecting the most efficient organisational form, and, on the other hand, the capabilities of the market mechanisms for performing such selection has been widely questioned (cf., for instance, Winter (1986)). TCE assumes that agents can select *ex-ante* the best governance structure minimising transaction costs (Brousseau, 1996), whereas selection occurs with multiple and nested selection criteria (e.g. organisational coherence, problem-solving, social interaction, technological learning,.... cf. Dosi, 1995).

Secondly, learning is described by TCE through the concept of “remediableness” (if agents select an inefficient organisational form, they have the possibility of changing it). In our view, this concept is not sufficient to explain the context of learning embedded in organisational arrangements (competency trap, organisational inertia, cf. Levinthal, 1992). We argue that learning cannot be described only by the minimisation of transactions costs and has to be understood within a perspective of knowledge building, with the possibility of individual and collective failures and the difficulty of choosing *ex-ante* optimal structures of governance. As recognised by Langlois and Robertson:

“.... the point is that one cannot have a complete theory of the boundaries of the firm without considering the process of learning in firms and markets. The reigning transaction-cost theories of vertical integration provide illuminating snapshots of possible institutional responses to a momentary situation. But they do not place those responses in the context of passage of time. Most theories of the boundaries of the firm are static in an important sense. They take the circumstances of production as given and investigate comparatively the properties of market-contract arrangements, internal organisation, and sometimes other modes of organisation. What happens, however when the technologies of production-and perhaps other environmental factors- are changing rapidly?” (Langlois and Robertson, p. 30).

In TCE, organisational forms originate from the inability of market mechanisms to channel and process information effectively. In the evolutionary/cognitive perspective, by contrast organisations are first of all loci of the creation, reproduction and modification of knowledge, and strong emphasis is put on the fact that the latter cannot be reduced to mere information processing (cf. Winter, 1982, Dosi and Marengo, 1994).

Thirdly, opportunism may be important in agreements, but it may be not the only value monitoring alliances. Two arguments can be stressed here. At the organisational level, transaction costs due to opportunism will decrease as learning takes place: with repeated interactions, hold-ups and moral hazard problems will be attenuated through the creation of norms of cooperation and reciprocity as well as routines (Langlois and Robertson, *ibid*). At the individual level, we argue that opportunism may co-exist with other conflicting values like trust (Noorderhaven, 1996). Indeed there is ample recognition that the human mind is not so monolithic and has to face judgement biases, cognitive dissonance and conflicting values (Tversky and Kahneman, 1978; Lazaric, 1996; Payne et al., 1992).

Our major point in this paper is that technological agreements should be mainly examined as *loci* of learning and that such a learning dimension cannot be fully captured by analytical tools which are confined to the mere consideration of transactions costs. A technological agreement has as its main purpose the generation of a new body of knowledge out of the encounter and interaction of two or more previously existing bodies of organisational knowledge. Thus the nature and the dynamics of the agreement cannot be fully grasped in terms of flow and processing of information among the partners and the costs and incentive problems stemming from such activities. Some recent approaches on collective competences (Hodgson, 1996), knowledge bases (Beije, 1996), decision rules for cooperation (Nooteboom, 1996) and on the paradox of learning (Bureth, Wolff and Zanfei, 1996), illustrate this cognitive dimension that we would like to explore further.

Moreover, learning cannot be reduced to mere information acquisition, but it implies interpretation, that is the generation of mental models, cognitive frames, categories which are not contained in and cannot be derived from information (cf. Dosi and Marengo (1994), Marengo (1996), Dosi, Marengo and Fagiolo (1996)). In social organisations and, *a fortiori*, in technological agreements, knowledge and learning processes are typically distributed [2] and a successful agreement is the one which sets the appropriate interaction mechanisms for generating new collective knowledge.

At least two orders of problems are involved in designing such mechanisms: a first issue concerns the communication and sharing of knowledge, a second one concerns the degree of commonality/diversity of the knowledge bases and the learning processes involved. On the first issue, in addition to the already widely analysed strategic problems of information disclosure, pre-strategic obstacles to communication and sharing of knowledge arise from its tacit component. Tacitness prevents knowledge from being fully communicated as it is not entirely transparent even to those who possess it. Nelson and Winter (1982) have broadly discussed the implication of tacit knowledge for economic organisation, but it is worth stressing that, as argued by Polanyi (1969), tacitness is much more widespread than usually considered in the evolutionary economics and economics of technical change tradition. While Polanyi refers mainly to the tacit components in skilful (mainly physical) activities, where of course no codified set of instructions could ever contain all the knowledge required, tacitness appears more generally in every act of interpretation and meaning attribution, as it depends on categories, mental models, cognitive frames which

[2] Knowledge is said to be *distributed* when a group of agents know something that none of the members of such a set (fully) knows. Of course such collective knowledge is generated by the social interaction mechanisms which connect together. Distributed knowledge must be distinguished from other forms of social distribution of knowledge such as *common* knowledge, when every member of the group knows something, he knows that all the others know it, he knows that all the others know that he knows it, and so on ad infinitum.

can only with difficulty be reduced to codified and communicable information. Thus, there exists a cognitive dimension in the problem of knowledge disclosure and communication, which can act quite independently of the strategic use of knowledge[3]. In particular, a fundamental issue in managing effective knowledge transfer in agreements is the provision of shared knowledge, languages, codes which provide the parties with the necessary capacity for effective communication and knowledge absorption. Among these, organisational routines play an especially central role, as they carry the memory of past interaction (cf. Cohen *et al.* (1995)). It is our claim that the dynamics of agreements cannot be fully analysed without referring to the characteristics and dynamics of the routines developed within the agreement itself.

A second issue concerns the trade-off between commonality and diversity of knowledge between the agents involved. First, consider the two (or more) organisations which form the agreement and in particular those parts of the organisations which are actually involved in it. If the knowledge bases of the parties are homogenous (that is the two originating organisations have analogous competencies) the agreement will probably face few coordination problems (at least as far as its cognitive aspect is concerned) but will be unlikely to provide opportunities for mutual learning of the parties involved, as each party’s knowledge is already similar to the other’s. On the other hand, if the knowledge bases are highly diverse, opportunities for mutual learning are high, but communication and coordination between parties are likely to be more problematic.

Similar trade-offs between commonality and heterogeneity of knowledge arise with respect to the relationship between the parts of each organisation, which are actually participating in the learning process and the rest of the organisation itself. If, possibly because of high learning produced by the agreement, this part of the organisation moves its knowledge basis further away from the rest of the organisation, the chances for the latter to be able to exploit such new knowledge are lowered. In other terms, cognitive coordination must be ensured between the agreement and the originating organisations in order to allow the integration of the new knowledge with that already existing.

[3] Indeed there are different meanings of tacitness. "Tacit à la Rosenberg" which refers to technical skills difficult to acquire without a long experience and practice. "Tacit à la Dasgupta/David" which refers on the incentives to disclose knowledge allowing rewards agents have for this disclosure process. "Tacit à la Dosi" refers finally on unaware, automatic and unconscious skills like mental models and heuristics used by agents for solving problems ans skills used during the repetition of a specific task. For a longer

It is worth pointing out that such cognitive coordination can be achieved through different organisational set-ups, ranging from highly centralised creation of codes, routines and practices which create and maintain a widely shared knowledge basis, to highly decentralised systems of knowledge sharing and communication which instead generate systems of local codes, routines and practices (cf., for some comparative analyses of different organisational set-ups, Crémer, 1992, Marengo, 1996).

Related to the trade-off between tacitness and codification, the trade-off between commonality and diversity and the trade-off between centralisation and decentralisation, is another fundamental “cognitive” trade-off which we believe constitutes a key dimension for the analysis of organisational forms: it is the trade off between generality and specificity. Generality of knowledge involves the possibility of applying it to a broad range of domains (Arora and Gambardella, 1994). Thus general knowledge is more likely to be redeployed, articulated in widely shared categories, and thus also more likely to be commonly shared and homogeneously distributed, and also more likely to be centralised. Fleck, in his description of the implementation of engineering systems, makes a similar distinction between generic and local knowledge: "The local practical knowledge is highly contingent to the particular firm concerned. It deals with the specific 'knowledge base' built up over many years of experience in carrying out the firm's business. Moreover, this local component is usually distributed among the many operatives involved in day-to-day activities. In many cases, this knowledge is tacitly embodied in skills and practices which have been gradually formed over a period and are not available in any other centralised or formalised form" (Fleck, 1994, pp. 641-642).

discussion on those aspects, see Balconi (1997). Here in our discussion, we are refering more particularly on tacit knowledge "à la Rosenberg" or "tacit knowledge à la Dosi".

## 3. Presentation of the case studies

This research is primarily based on observations made during a study of the robotic sector between 1992 and 1994, in which 8 agreements were followed in their historical development. The aim of this investigation is to show how firms try to generate and absorb knowledge through technological agreements. We focus our attention on 8 agreements between users and producers and try to see how cooperation evolves between the two partners, how organisational co-ordination emerges and how specific assets are created.

The agreements involve European firms of different nationalities: two agreements involve only French partners, two only German partners and one only Italian partners; the remaining three involve partners of different nationalities. Data were collected by interviews which were carried out during a period of two years, allowing for the study of the different interactions which intervened before the establishment of the formal or the informal alliance. A two-year observation period was also important for updating information in the case of organisational change between the two firms (this was particularly important in the case of Renault -Renault Automation).

These kind of agreement between automobile and robotic firms usually have the feature of being motived by the goal of knowledge generation (contrary to what usually happens in agreements which mainly serve the purpose of increasing production efficiency or reducing financial risks) and by technological complementarities. In our view these complementarities between partners provide stronger incentives to exchange and share a broader range of information and knowledge than is the case where partners simply cooperate to reduce production costs or share financial resources.

All the technological agreements considered here are characterised by high degree of quasi-independence of the joint venture from the parent firms. This feature allows us to analyse the agreements in relative isolation, whereas stronger and more frequent links between the parent firms and the joint venture have an influence on the process of knowledge generation. A general pre-condition for assuming quasi-independence of the joint venture is that the parent firms be themselves independent entities: when in fact partners already have strong links it seems hardly possible that what they give rise to can be properly defined as an agreement. For this reason, we study firms which do not have reciprocal financial links. Two cases however appear as partial exceptions. First, the case of Renault and Renault Automation has been kept because the latter firm increased its independence during the 80's and became autonomous at the beginning of the 90's. The case of Comau and Fiat was also kept even if Comau still has a financial link with Fiat, because of the great independence of Comau in terms of technological creation.

Another criterion for selection of alliances was the desire to analyse agreements whose operations had terminated. In this way it was possible to give an overall evaluation of the agreement. This criterion allowed for qualitative evaluation of the impact of the agreement on organisational conditions, the nature of the knowledge produced, the dynamics of learning, the nature of assets and their possible redeployability in others agreements. As the number of producers in the robotic sector is very small, we were also able to take into consideration all agreements or interactions which had taken place before the alliance.

The automobile sector was chosen because car manufacturers have a long-standing commitment to producing their own equipment, and have thus developed internal competencies in the design of robots. Citroën, BMW, Fiat and Renault have played a very active role in developing robotic know-how by beginning to design their own robots in their plants before externalising this activity. Most of the users have therefore a specific experience and may be considered in some cases as "lead users"[4].
This specific context helps to have a "history" of industrial relations between the firms and to illuminate some particular transfer of knowledge realised in the agreements between the two firms. In this context it seems to us interesting to see how learning might be sustained by these initial conditions and how learning can evolve in a non deterministic way according the nature of assets engaged in cooperation.

The content of the agreements may concern the development of various projects. Some agreements concern the development and the implementation of software either for monitoring the robot or for improving the process by implementing an "off line" system which provides data before the launching of the car. Some agreements include rather sophisticated opto-electronic developments concerning the robots for assembly lines.

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[4] For a longer discussion on this point and some recent illustrations on the role of users in this dynamic, see Kong Rae Lee (1996), Hippel and Tyre (1995), Balconi (1996) and Fleck (1994).

These projects are very uncertain in their development and in their commercialisation because each plant has its own configuration and its own constraints affecting the automation of the assembly line and which introduce different kinds of complexity. Software for welding robots poses fewer problems because the users have a considerable experience with this technology whereas software for the assembly is not very well tested. In short, all the agreements related to the development of rather uncertain technologies, of which the partners had little experience. Only one agreement is rather different: the Renault -Renault Automation case concerns the development of a hydroelectric system in the powering of the welding robot.

Concerning organisational forms, agreements are established in joint venture with the principle of an even sharing of the expenses. Informal agreements are rather frequent because the mutual trust developed in previous interactions acted as a substitute for formal contracting. In their implementation, formal or informal agreements are not very different as regard technological features. One agreement is dissimilar in its nature: the case of OEM agreements concerning BMW and Kuka for the commercialisation of a specific system first tried out in the user plant. A complete presentation of the agreements is to be found in the following table.

Table 1: Presentation of the case studies

| Partners | Year of the agreement | Type of the agreement | Field of the agreement |
|---|---|---|---|
| **Renault** French automobile firm<br>**Renault Automation** French robot producer | 1985 | informal agreement | Development of a specific hydro-electric system |
| **PSA** Automobile producer<br>**Renault Automation** French robot producer | 1990 | *joint venture* | Laser yag designing in welding system |
| **Renault** French Automobile firm<br>**ABB** International robot producer | 1991 | *joint venture* | Development of an "off line" software |
| **BMW** German automobile firm<br>**Kuka** German robot producer | 1985 | OEM | Development and commer-cialisation of a monitoring system |
| **Mercedes** German automobile firm<br>**Kuka** German robot producer | 1989 | informal agreement | Development and of an opto-electronic system |
| **Fiat** Italian automobile firm<br>**Comau** Italian robot producer | 1984 | informal agreement | Development of an electronic welding system |
| **Mercedes**, German Automobile firm<br>**Comau** Italian robot producer | 1991 | *joint venture* | Development of an electronic welding system |
| **Citroën**, French automobile firm<br>**Comau** Italian robot producer | 1989 | informal agreement | Development of an "off line" monitoring system based on artificial intelligence |

In order to explain the content of technological agreements in terms of the knowledge produced, we need to see how technological creation may be supported by intangible investments allowing for the coordination of distant corporate cultures. Indeed establishing these intangible conditions are often a first step before making material commitments. Learning in these conditions is a very cautious process supported by relational investments and organisational rules which help to combine know-how in a coherent and shared way (Lazaric and Wolff, 1996; Lazaric, 1994; Bureth et al., 1996). Let us examine the different kinds of assets produced in these agreements and their characteristics.

## 4. Production of specific assets and their transfer

In order to occur, learning needs some specific commitments both in tangible and intangible assets for sustaining cooperation (Lazaric and Wolff, 1996; Gulati et al., 1994). These resources play two roles: on the one hand they coordinate diversity of knowledge coming from the association of two different corporate cultures and on the other hand they preserve cooperation by creating irreversibility's. If the partners do not commit some resources, cooperation has little chance of succeeding. Firms engaging in cooperation have to make a bet on the future rents from the alliance and must commit some resources without having any degree of certainty about the returns on this kind of cooperation. In fact this process is not an automatic one and needs time for creating a climate of trust and for finding some organisational rules able to coordinate the diversity without bringing into question the identities of the two firms involved (Bureth et al., 1996).

Specific technological assets can be embodied in some specific equipment but can also include some collective competencies, as we usually find in the design phase. They can be relational through the creation of many ties during the project or before its implementation. These assets are very important for mobilising new combinations of knowledge which cannot be created if conflicts between firms exist. In this way, these relational assets are sustained by personal trust coming from close interactions between individuals working together. Finally as we shall show later, relational assets are the first step for improving coordination by helping the creation of some appropriate organisational mechanisms such as rules or routines[5]. From another side specific assets either technological, relational or organisational produce some strong externalities and increase returns to the ongoing learning (Levinthal and March, 1981; March, 1991).

These externalities promote exchange of information and knowledge that create a degree of lock-in which discourages the cooperation with others partners. That is the reason why we look very carefully at the nature of assets produced because some part of them may be locked in and difficult to transfer while some others may be re-deployed in different

[5] We would like to stress that building competencies in agreements cannot overlook the role of human capital which play an active part in the transformation and adaptation of the technology. These relational and organizational resources are important for increasing the problem-solving capacity of each firm and may be considered as assets (Winter, 1987).

agreements giving stronger externalities to initial investments. The indivisible assets or the partly re-deployable ones play an important role in enabling firms to benefit from cooperation and avoid excessive specialisation occurring when they are unable to exploit with other partners benefits from previous collaboration (Lazaric and Wolff, 1996; Bureth and alii, 1996). Let us discuss more precisely the different types of assets before seeing their potential redeployability.

*** Technological assets**

Technological assets first are usually engaged in the cooperation after some period of mutual observation (one or two years depending of the previous interactions before the agreement). For example all the firms have produced technological assets which the redeployability is linked. In the case of ABB and Renault, by contrast, firms have not succeeded in committing shared resources for the creation of some joint artefact. These later two firms were cooperating for the first time together and discovering the way they were working, and at the same time the difficulty of attuning their rather distant practices. ABB was used to implementing general principles which were easy to transfer from one user to another one for the reproduction the automation process with few specifications. This firm as an international producer in this field, was not used to making a lot of concessions for its user. From the other side Renault was cooperating with other foreign robot producers and was rather demanding about the specificity of technical solutions. If this firm was interested in a different way of implementing robots, it did not question its own corporate culture. So the cooperation between the two firms failed to build any technological assets because in the climate of mutual observation it was difficult to put together current element of know-how and to combine them. At this stage cooperation remains merely a matter of eye contact without a credible commitment for sustaining it.

Two others case studies show high degree of non redeployability (examples of cases of Renault and Renault Automation and of Renault Automation with PSA). These cooperation are very different in nature. The first is non redeployable because the technological assets are exploiting a rather traditional trajectory based on hydraulic principles specific to Renault and difficult to transfer to another user (all users were at this time engaged in electric trajectory as well as in the motorization and in monitoring principles) (Lazaric, 1992). PSA and Renault Automation on the other hand were engaged in a very risky project concerning a laser Yag for exploring a new way of cutting metals before placing the wheels. This project including a system of censoring that was so specific to user needs that it was difficult to transfer it in another plant.

*** Relational assets**

Technological assets are supported by relational conditions because firms need to know each other before engaging in specific investments. Communication between the different corporate cultures is essential otherwise alliances may be limited to an association of diverse knowledge without any absorption and transformation of it. These relational assets provide a mutual understanding and facilitate absorptive capacity: "Just as prior involvement in a given technological domain facilitates the understanding and interpretation of subsequent information within that domain, prior information sharing with a given individual enhances the interpretation of subsequent information exchange. The particular "dialect" of different actors will be more effectively decoded" (Levinthal, 1996, p. 9). Shared language will be an important step for making current practices explicit and for trying to share elements of tacit knowledge embedded in them.
The transmission of collective knowledge through narration gives a better idea of the way the firms work and solve in situ problems. In this construction of shared languages, there is an effort of translation for expliciting practices and trying to incorporate some of them in a more formal way. This narration is very important because some knowledge may be observable but difficult to articulate and to codify (Winter, 1987; Senker, 1995). Close links in a small community help to observe and to teach some of it (Brown and Duguit, 1990)

In our case studies a shared language has been created in almost all the agreements and sustained by prior interactions. In some cases the language is common because historical and organisational reasons have created a sort of commonality between the different firms (in the case of Renault and Renault Automation and in that of Fiat and Comau). Sometimes shared language is present despite an apparent cultural distance between the two firms (Citröen and Comau; Mercedes and Comau). In this later case, prior interactions played an important role in implementing a shared professional language between partners. In the case of Renault and ABB, the cultural distance between the two firms brought some confrontation in the current practice without creating a shared language which unified them.

Communication and shared language are supported by a useful lubricant: trust emerging by close contacts between individuals who are cooperating together. In this context we make a distinction between "personal trust" emerging from prior knowledge between individuals and "organisational trust" concerning shared beliefs between two organisational entities (Dodgson, 1993). Personal trust concerns subjective beliefs: "the decision of an agent to place trust in another depends on her believing that he will act in a way that makes her better or worse off. In general when we say that agents trust one another we are referring to this background of belief among them" (Lazaric and Lorenz, 1995, p.2). These beliefs are not given but take place at the same time that learning occurs: they are inductively constructed at each step of the cooperation and opened to transformation if some agent produces some contradictatory or ambiguous signals. Trust in cooperation may begin by some personal links but this intangible asset will be less fragile if it is not limited to bilateral ties and interpersonal relations and if this belief can be extended to the members of organisations. [6]

This belief is more bilateral in the relation of PSA and Renault Automation and in the case of Citröen and Comau and does not exist in the cooperation between Renault and ABB. It is interesting to observe here that rapid success in technological projects may have a significant impact on this belief and may be a substitute of years of familiarity (for example, in the case of Mercedes and Comau initial success rapidly triggered this dynamic). More generally organisational trust is most of the time based on competencies, ie the capacity one partner has for solving a problem, even if the situation is characterised by strong uncertainty[7]. 'Competence trust' between organisations refers to the beliefs that trading partners are capable of living up to their commitments. This notion is distinct from the belief that partners are intending to uphold their promise: 'competence trust' refers to

[6] According Livet and Reynaud's definition, organizational trust depends on the members of a group involved in some collective endeavour holding 'reasonable' belief that each is implicitly committed to it (Livet et Reynaud, 1997).

[7] For a similar point of view on competence trust in the japanese machine tool between users and specialized suppliers, see Lee, 1996,p.494.

the capacity to undertake certain tasks whereas 'intentions trust' refers more on the partner's honesty to keep its promises (Sako, 1997)[8].

With regard to our previous discussion most of our case studies show strong ties between firms and organisational trust. This result has to be analysed carefully because of the nature of the links before agreement takes place. Most of the time the agreement is just the formalisation of previous work over many years. Mercedes and Kuka for example were interacting from the end of the 70's. It is not surprising in these conditions that organisational trust exists! Fiat-Comau and Renault -Renault Automation are in the same position whereas Mercedes-Comau have cooperated for only for five years but have always succeeded in implementing very innovative and risky projects. Organisational trust is in this latter case more based on competence and a very good understanding facilitating the transfer of solutions experienced in other agreements and their hybridisation according to new constraints, than intentions or familiarity.

***Organisational assets**

Rules are collective knowledge that economise individual knowledge (ie they substitute complexity of individual knowledge for the simplicity of collective knowledge (Favereau, 1989, 1995). More precisely, a rule is a prescription one may conform to and which indicates what behaviour is allowed or prohibited in a particular context (Shimanoff, 1980). In the case of cooperation, rules bring some mechanisms which may facilitate coordination between two distant corporate culture. Rules may be considered as patterns of actions experienced in a local context before being repeated. They may be transformed and reproduced through time if they tend to bring some robust responses to organisational coordination. We make a distinction between local rules which are specific domains and are produced in some particular context which is difficult to reproduce, and "meta rules", non domain-specific because there is ample scope to interpret them and a capacity to reproduce them in another context because they are general enough in their principles to bring some methodological knowledge possible to transfer or to adapt in another agreement. "Meta rules" are defined as redeployable assets.

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[8] If these notions are conceptually distinct, they are often related in practice because the belief that your partner is able to undertake certain tasks is also related to its intentions to undertake them not in an opportunistic manner.

The first "meta rule" that we observed can be called the rule of "step by step". Most of our case studies show that firms started by making small commitments to each other and then progressively increased their commitments depending on the quality of their exchange. Learning follows in this case an incremental process. Firm generally begin their cooperation on some rather minor technological problems. Cooperation in Germany between Kuka and Mercedes and Kuka and BMW for example began with Fraunhofer institutions on small technological projects partly supported by the institute. If partners succeed in their collaboration including a third partner they may begin other more significant collaborations. For example the robot producer has been involved in technological developments for a new car model in BMW and Mercedes with more important financial commitments. This process of engaging more investments in cooperation took as long as three to four years and has been strongly supported by relational ties. At the same time that engagements were increasing, meta rules on appropriability were constructed to facilite transfer of knowledge outside agreements.

This other meta rule was guiding technological appropriability by fixing some general prescriptions about transfer. In this way, it stabilises technological development allowing clarifications in the transferability of technical solutions and providing a compromise between collective interests (ie the rapid dissemination of innovative solutions) and the individual interests of the user (ie to preserve the exclusivity of his solution). The cases of BMW-Kuka and Mercedes-Kuka are very illustrative of this kind of dynamic. For example in the case of the creation of specific off-line software for monitoring the robot, the technical solution and its methodology are transferred, but the data of this specific software remains confidential. The general principle is to maximise the dissemination of innovative solutions after maintaining exclusivity for a short time (around 24 months) helping firms to convert knowledge in further cooperation and to benefit from prior experience. Quote here that users and producers' interests are contradidactory because a user has a strong incentive to preserve the confidentiality of technical solutions as long as possible to benefit innovation's rent whereas the supplier has an interest in transmitting as soon as possible this collective knowledge in order to exploit this innovation with different users. Firms have to find appropriate compromises for separating private from public knowledge and have to create temporary rights for each participant (data in software programmation may remain confidential and may be re-used in others agreements in excluding some specific information from user like the site configuration). If firms have not enough experience and general knowledge about those aspects, they are not able to find a suitable compromise between private and collective interests[9].

Comau for example has also a great capacity to combine knowledge and to convert it in different cooperations by fixing meta rules producing methodological knowledge which is easy to transfer in to different contexts. ABB from the other side set down by some organisational rules rather similar from one cooperation to another but does try enough to adapt rules with different contexts. ABB gives some general principles about the creation of an "off line" software but this firm is not flexible enough to operate any hybridisation with user conditions. This impedes some new combinations of knowledge and does not enforce absorptive capacity for the user.

Some others local rules deal more with problems of uncertainty. In order to face difficulties in technological creation and unexpected constraints, the rule is to continue to invest for the project at least one year even if the initial results seem not to be very promising. This specific rule has been very useful in the case of the Mercedes Comau agreement because firms encounter local problems with the Sindelfingen plant. Equipment required different unpredictable adaptations. Comau incited its partner to reinvest for one more year and find finally new ways to design equipment according specific indications during the two lasts months. This solution proved to be very innovative and a useful means of exploring knowledge coming from different agreements. This local rule which seems to be trivial is important because technological projects often encounter problems of delay and of adaptation to local conditions. If partners are not able to deal with this uncertainty by changing the terms of initial contracts engaged at the beginning of the joint venture they have be disappointed by the cooperation. In fact partners have to adapt their own competence and their requests during the project for supporting this collective work. Without compromises from both sides cooperation is likely to disappoint partners. The complete presentation of assets produced is to be found in the following table.

[9] For a more global description of private, public and collective knowledge in science, see Cassier and Foray, 1996.

Table 2: Assets created in agreements

| | **Technological and relational assets** | **Organisational assets** |
|---|---|---|
| **Renault and R A** | • Technological assets non redeployable<br>• Common language | • Local rules<br>• Organisational trust |
| **PSA and R A** | • Indivisible technological assets<br>• Shared language | • Local rules<br>• Personal trust |
| **Renault and ABB** | . No technological assets<br>• High cultural distance between firms | • Meta rules<br>• No trust |
| **BMW and Kuka** | • Technological assets partly redeployable<br>• Shared language | • Local and meta rules<br>• Organisational trust |
| **Mercedes and Kuka** | • Technological assets partly redeployable<br>• Shared language | • Local and meta rules<br>• Organisational trust |
| **FIAT and Comau** | • Technological assets partly redeployable<br>• Common language | • Local rules<br>• Organisational trust |
| **Mercedes and Comau** | • Technological assets redeployable<br>• Shared language | • Local and meta rules<br>• Organisational trust |
| **Citroën and Comau** | • Technological assets redeployable<br>• Shared language | • Local and meta rules<br>• Personal trust |

## 5. Towards a taxonomy of knowledge created in technological agreements

Our next step, in this section, is to see more explicitly the link between assets and knowledge produced in agreements for going inside the "black box" of the generation of specific capabilities with regard to organisational contexts. We try to stretch a taxonomy of knowledge created and to give some elements of interpretation concerning the dynamic of learning. This taxonomy tries to bring some light to bear on the nature of knowledge according the level of codification, the level of diversity, the level of generality and the level of centralisation[10]. We look very carefully at the link between the level of generalisation and other kinds of knowledge (according the level of codification for example) and try to see if any kind of knowledge has an impact on the exploitation and exploration trade-off supporting the learning process.

### 5.1 Characteristics of knowledge produced

#### * Level of codification

Knowledge generated inside the agreement is most of the time both tacit and codified[11]. This knowledge has initially been taught through direct experimentation. After a period of teaching, some codification has been done. This process is not trivial because robotic production is complex and requires different bodies of interrelated knowledge. This level of complexity calls for specific procedures in order to codify knowledge without excluding its tacit dimension. In practice we observe that engineers have to have worked together at least one year in order to explain their own practice and their idiosyncratic needs. After this period of know-how exchange, some groups try to memorise the shared knowledge through

[10] The taxonomy relies upon a qualitative evaluation of knowledge produced. Empirical facts have been collected during interviews and update when the organizational entity has been transformed. Informations are used here more to bring some light on the historical perspective of competencies' building than to bring some accurate measures of knowledge created.

[11] As recognized Senker, in the robotic sector, tacit knowledge coexist most of the time with codification procedure because of the distributed knowledge incorporated in each firm. " Limits to codification exposed by attemps to produce general solutions to automation as shown by the history of industrial robots. The original vision for this technology was the production of a universal replacement for human labour. In the event, families of different special-purpose robots have emerged, adapted to the needs of specific users and specific applications. Moreover, the successful implementation of robots depends on' detailed and specific knowledge about the particular situation in which it is proposed to introduce a robot, and about the technology itself" (Fleck, 1983, p. 67); beside being widely distributed throughout an organisation, much of this knowledge is tacit and uncodified "(Senker, 1993, p.221).

a procedure of "reporting". This consists in writing all the steps involved in tasks and the objectives for the next step. In the case of Mercedes and Comau, firms began by solving the problem of plant configuration. Secondly, an internal report in the agreement was discussed for planning the next stage which consists in the creation of a specific software able to take in consideration all these parameters. This rule of reporting also helps to summarise and to articulate previous tasks and to see their evolution. An important consequence was that this procedure helps to simplify the current work and to generalise the local knowledge. If this procedure of memorisation was perceived at the beginning for engineers as a constraint which impedes the organisational coordination to go quicker, after some period (between one and two years) they understand its utility and were not any more reluctant to apply and to improve it.

In most of our cases studies tacit knowledge coexisted with more codified forms (memorised in internal reports or data). Nevertheless some agreements show an important degree of tacit knowledge. BMW /Kuka and Renault /Renault-Automation cases show some difficulty in the transformation of local knowledge in to general. Some reasons explain this process. Firstly, codification is as long as it is costly and requires particular attention. Secondly, when firms are cooperating over a long period they think that there is no necessity to articulate prior tasks. This strategy may be risky in the case of high turnover as we saw in the Kuka firm. After a conflictual period the robotic firm has renewed the contracts of a large number of employees. Some of them were dedicated to the project with BMW and have had great difficulty understanding current procedures and prior work.

Codification does not mean an easier access from outside the patnership to technological or organisational capabilities. Codification does not necessarily decrease the complexity of the product and does not necessarily facilitate the absortive capacity by others users because of the need to adapt technology according plant's specificity. Robotic technology has to cope with many utilisation’s in different contexts, producing situated knowledge that is not easy to transfer. That the reason why this process does not allow a free access for this technology. As Balconi recognised, the problem of non easy transferability goes beyond codification because of the need of transforming technology according user's needs and of providing practical demonstration on site to transmit know-how and by explaining know - why (Balconi, 1996).

Three types of problem are related to the dynamic of codification. Firstly, the incentive to codify tacit knowledge and to articulate in general categories (Nelson and Winter, 1982). Secondly, the costs and the benefits of this articulation on new media generate a transformation of traditional know-how and know-why (Lundvall and Johnson, 1994). Thirdly, the cost of this codification which will be related to the nature of the environment. In an environment characterised by high uncertainty about technological trajectories, incentives to codification are rather low. In a stable environment however benefits are more tangible (Cowan and Foray, 1996). In the robotic sector, characterised by an intermediate uncertainty about technological development, firms find some benefit from codification but also some paradoxes due to the sophistication of robotic use[12].

*** Level of diversity**

In most of our case studies shared knowledge was very important for the starting up of the agreement. In the case of very diverse knowledge like ABB and Renault, firms have difficulty creating assets and do not trust enough to exchange tacit knowledge. In this example, firms explore some new ideas but do not have enough incentive to exploit them outside this locus of experimentation. Here shortness in the relationship is an important factor because the confrontation of the different corporate cultures has not been overcome by familiarity and personal links inside the agreement. Shared knowledge is most of the times connected with a shared or common language between firms which decreases some cultural distance between the two entities. As trust takes time to be constructed, the absence of prior ties between firms play a negative role in the creation of specific knowledge.

In the case of Renault and ABB, firms in their agreement were confronted with different visions for solving problems (technical or organisational ones) and were not able to find a suitable compromise in order to absorb new background knowledge. On the other hand, the gap between two different capabilities was too distant with empirical and tacit knowledge used by Renault and codified knowledge used by ABB allowing the international firm to offer technical solutions with any user. The gap between the firms did not allow the

[12] Benefits from opto-electonics in some applications like the fitting out in last operations of assembly line, have been hardly questionned because the productivity obtained by using opto-electronic systems like sensors is lost with a decrease of flexibility in the case of a breakdown. In these applications, human labor with its tacit knowledge is fareaway more flexible ! Nevertheless in traditional operations like handling or manipulations, uncertainty is weaker and advantages to codification higher.

combination of different types of know-how or progress in the exploration of sophisticated "off-line” monitoring system.

*** Level of generality**

In terms of level of generality, firms encounter difficulties in finding an appropriate balance between local and general knowledge. Local knowledge is most of the time associated with local rules and non redeployable assets (as in the cases of Renault and Renault Automation, PSA and Renault Automation, BMW and Kuka, Mercedes and Kuka). Firms create knowledge but find it hard to accomplish some generalisation for exploiting it in others agreements. Their investments remain local and have lower returns that in a case of possible transfer. The most illustrative feature of this local knowledge is one produced inside the Renault and Renault Automation case. Know-how was created according the idiosyncratic needs of the user in the trajectory of hydraulic servo-mechanism for welding. Renault-Automation has in fact little possibility of exploiting this technical knowledge with other users and to diffuse its local competence in this field. Indeed all users during the 80's adopted electrical servo-mechanisms in powering and have slowly deserted hydraulic or pneumatic servo-mechanisms in the connecting of components with electric systems. This extreme case shows how crucial is the trade-off between general and local knowledge in avoiding competency trap.

General knowledge is as well based on technical principles as organisational ones. We mean that the way knowledge is produced and organised according to the degree of specificity or generality plays an important role in transferring knowledge more than the only process of codification. In some cases, codification may be interconnected with the level of generality but this process is not automatic. Moreover, codified knowledge may be included in local knowledge because even if you produce codified know-how, you do not have the guarantee to extract enough methodological knowledge to exploit it in another agreement.

Local and general knowledge was generated by Comau during its agreements with foreign partners. This firm has in fact a great ability to extract methodological knowledge and to re-exploit it with new partners for the production of new combinations of know-how. For example, a long-satnding task between Comau and Fiat created "Robogate", a celebrated welding system integrating robot and engineering processes into the same conception. This solution, allowing a good synchronisation of product and process, is a major innovation, based on a specific methodology for welding. The cooperation between the two firms was intensive between 1976 and 1982 and less regular after this period. Fiat was however not willing to invest in new technological cooperation and wanted to exploit a technical solution to improve the process, Comau began to explore new technical opportunities with foreign users. Agreements with Citroën and Mercedes were illustrative of this new way of working. This exploration was crucial for Comau which had an important know-how in the machine tool business and needed to transform it by integrating new kinds of knowledge in electronic trajectory. The cooperation between Comau and Mercedes in 1991 for a welding system, which took as its dominant design the "Robogate", gives a better idea of this dynamic. In the case of the "Robogate", user and producer were adapting the welding system to the plant configuration, but the particular configuration of the Sindelfingen changed the routinized way of working. These new constraints transformed the welding system bringing new innovative solutions in the way the robot approached the car. Instead of exploiting the same methodology, Comau managed in recombining existing technical solutions and organisational procedures for improving and renewing previous innovations. This cooperation which created the "Rotogate" benefited from important learning externalities with other users. Comau had in 1986 began to work with BMW for improving the "Robogate" on the E 30 model. Comau and BMW concluded an informal agreement two years later for improving this system during the E 34 launching. This very ambitious project failed because of time delays and excessive material investments for the two firms. The failure was relative and gave Comau experience useful in its cooperation with Mercedes three years later. Comau was able to create a specific solution, to use this local knowledge and it had the capacity to extract abstract knowledge from practice.

As we can see, most of the time local and general knowledge is complementary. As illustrated by Fleck in his concept of "learning by trying", successful implementation of a technology is "a matter of finding a synthesis of local and generic knowledge adequate for meeting particular requirements" (Fleck, 1994, p. 647).

*** Level of centralisation**

Knowledge produced in agreements is in most cases decentralised. This seems rather obvious because alliances are sub units, quasi-independent of their owners. This quasi autonomy is important for creating an entity able to solve problems without being constantly monitored by a hierarchical structure. The level of effective decentralisation has to be carefully examined. Kline and Rosenberg have underlined this point by showing the advantages of Japanese firms for innovating in quasi-horizontal organisation (Kline and Rosenberg, 1986). The aim of this horizontal organisation is to cluster links between different departments and to speed feed-backs inside each step of the innovative process. Small structures or decentralised units may be more able to create local knowledge and may provide strong incentives for supporting innovative projects (Nonaka, 1994).

Our case studies show an important degree of decentralised knowledge. Two agreements contradict however this principle. Renault and Renault Automation is illustrative of a weak level of decentralised knowledge which has to be explained with the story of the firms. Renault Automation became independent at the beginning of the 90's, but has strong links with its user because the robotic activity was initially created in its department before being a distinct entity. In this historical context, Renault has always monitored its robotic supplier and considered it as a part of its own activities. Although the firms became autonomous from a juridical point of view at the beginning of the 90's, historical conditions have created some path dependence in technological creation. In the case of Comau and Fiat, where links are considerable, industrial relations are different. Fiat began its robotic activity by incorporating a firm coming from the machine tool sector. Comau has a different corporate culture and was used to working with different industrial partners. The creation of internal competencies in the field of robotics was made through constant and regular work with Fiat and through different interactions with others partners (Italian or international). Although Comau still has some financial links with Fiat, the robotic unit is more independent in its technological creation than its French partner because not monitored by a single user. This explains why Comau was able to combine different backgrounds of knowledge and to be very innovative during the 90's.

## 5.2 Transfer of knowledge and dynamic of learning

Considering now the dynamic of learning, we have to take in consideration different kinds of knowledge generation. In the first case, firms in cooperation have both learned and increased their internal level of competence (cases of Mercedes and Kuka, PSA and Renault Automation, Fiat and Comau, Mercedes and Comau, Citröen and Comau). PSA has for example tried to help Renault Automation to absorb some competence in electric trajectory by working with its producer in designing electrical robots and in sophisticated opto-electronics projects. PSA has also experimented the first electrical robot produced by Renault Automation in 1985 and has generated an important feed-back for improving the dominant design. From the other side, PSA has benefited from considerable information on the automative process (simplification on the line for bringing less complexity). The learning dynamic has explored new paths inside the electrical and opto-electronic trajectory and at the same time has exploited new ideas for improving the technical solutions created and for implementing them in a more realistic way (the laser Yag solution for assembly required some important simplifications in order to be robust enough on the line).

Agreements with Comau (in the cases of Fiat, Mercedes and Citroën) show a similar dynamic of the mutual benefits of cooperation with an innovative dynamic characterised by both exploitation and exploration. Comau begun its innovative project with Fiat and has created the Robogate, a major innovation in the robotic sector. This creation is in fact an automative product integrating robots and various pieces of equipment on the line. Without important requirements coming from its user and a high level of learning by doing, Comau would have not been able to create such a successful piece of equipment in foreign markets. This project, patented at the beginning of the 80's, was transformed for new plant configuration at the beginning of the 90's. Automobile firms needed more flexible equipment and redeployable processes. Rationalisation in this sector required flexible lines adapted to small batches which could be easily transformed according to user needs. This equipment also needed to be reconverted in others plants. The"Robogate" was not flexible enough. That the reason why Mercedes and Comau created a new line benefiting from both competencies (the competencies of Mercedes in flexible automative pocess and the competence of Comau in designing equipment including robots). This process called "Rotogate", patented in 1991, has been recreated with other users according their idiosyncratic needs. Comau has developed an internal competence allowing the firm to transform and to combine its specific equipment with different backgrounds of knowledge (the case of Citroën and Comau illustrates this combinative capacity). Comau proposes a general methodology flexible enough for being adapted to user needs. This helps it to explore new ways of solving problems and to exploit prior knowledge coming from different agreements by generalising and transferring local know-how.

Other case studies show a different way of learning through the unilateral transfer of knowledge. BMW and Kuka Renault and Renault Automation illustrate the case of lead users which have begun to produce robots by themselves and tried to transfer this competence to their own producer. BMW, for example, started to build robots in an experimental way in the middle of the70's. This automobile firm developed some innovative solutions (notably the portical robot for welding) and decided to exploit this technology and to improve it with Kuka by giving to this firm a property right to exploit some technical solutions (licence of exploitation). Kuka thus absorbed considerable know-how in this sector and was able to develop innovative solutions on her own some years later. This firm was able to transform this local knowledge and to explore different ways of solving problems in the 80's and has developed important innovative solution in the electrical trajectory allowing it to compete with international firms like Comau and ABB. Its explorative capacity was also reinforced by major collaborations with Fraunhofer institutes (IPA and IPK) helping it gradually to absorb new skills in opto-electronics technologies.

Contrary to the case of Kuka and BMW, Renault and Renault Automation did not succeed in extracting local knowledge and transferring it in others agreements. This low combinative capacity may be explained by some historical events. This firm was constantly monitored by its user who had previously created the robotics department and was monitoring this activity according its specific needs. This impedes the producer from exploring different backgrounds of knowledge and transforming its competence according to international competition. To summarise briefly, the transfer of knowledge coming from its specific user "locked" Renault Automation into the hydraulic trajectory and gradually evicted it from international markets.

In the middle of the 80's, Renault Automation tried to absorb different backgrounds of knowledge by cooperating with other users (notably PSA), but encountered many difficulties to go beyond its existing competence’s and has not enough know-how in the electronic trajectory to compete with foreign producers. The exploitation of the hydraulics technical solution progressively decreased its capacity to solve various problems and prevented it from benefiting from the diversity of knowledge of others users. That the reason why the firm was not able to propose innovative solutions at the end of the 80's and has not really succeeded to in regaining its lead in this field.

The presentation of the cognitive characteristics created in agreements are to be found in the following table.

Table 3: Dynamic of learning and cognitive characteristics of agreements

| | *Characteristics of knowledge produced* | | | | *Characteristics of transfer* | *Characteristics of learning* |
|---|---|---|---|---|---|---|
| | *Level of diversity* | *Level of generalisation* | *Level of centralisation* | *Level of codification* | *Level of absorptive capacity* | *Level of exploitation or exploration* |
| **Renault and Renault Automation** | Shared Know-ledge | Local knowledge | Links frequent between owner firms | Tacit knowledge more important | Transfer of knowledge from Renault to Renault Automation | Exploitation and competency trap in hydraulics technical solution |
| **PSA and Renault Automation** | Shared and diverse know-ledge | Local knowledge | Decentra-lised knowledge | Tacit and some codified knowledge | Transfer of knowledge for 2 firms in a rather symmetric way | Exploitation with some exploration |
| **Renault and ABB** | Diverse Know-ledge | General knowledge | Decentra-lised knowledge | Codified knowledge | No transfer | Exploration |
| **BMW and Kuka** | Shared Know-ledge | Local knowledge | Decentra-lised knowledge | More tacit than codified | Transfer of knowledge from BMW to Kuka | Exploitation |
| **Mercedes and Kuka** | Shared Know-ledge | Local knowledge | Decentra-lised knowledge | Tacit and codified | Transfer of knowledge for the 2 firms | Exploitation and exploration |
| **FIAT and Comau** | Shared Know-ledge | Local and general knowledge | Links frequent between owner firms | Tacit and codified | Transfer of knowledge for the 2 firms | Exploitation and exploration |
| **Mercedes and Comau** | Shared Know-ledge | Local and general knowledge | Decentra-lised knowledge | Tacit and codified | Transfer of knowledge for the 2 firms | High exploration and exploitation |
| **Citroën and Comau** | Shared Know-ledge | Local and general knowledge | Decentra-lised knowledge | Tacit and codified | Transfer of knowledge for the 2 firms | Exploitation and exploration |

## 6. Conclusions

This paper was intended as a first attempt to shed new light on the nature and dynamics of inter-firm technological agreements by focusing on the learning aspects. As the main purpose of such agreements is to create new competencies, we have argued that the nature and characteristics of the knowledge bases which originate such learning process play an essential role in defining the directions and the outcome of learning. In particular, the case studies examined in this paper show a link between the degree of generality of the knowledge produced in the agreement and the capacity of exploring new learning paths. This explorative capacity also appears linked to the ability to generate meta-rules.

In many agreements characterised by an explorative capacity (Mercedes and Kuka, Fiat and Comau, Mercedes and Comau, Citroën and Comau), the assets produced are totally or partly redeployable and supported by meta rules (except in the case of Fiat and Comau where path dependency in the relationship impeded the creation of more general rules). Most of the time knowledge is general (in the case of Mercedes and Kuka nevertheless knowledge is codified but also local) but also supported by local knowledge in order to have the possibility of understanding the users' needs. The explorative capacity may be reduced to pure exploration without transfer of knowledge and shared assets if firms are not able to reduce the distance between their corporate culture and to combine some knowledge together (see the case of ABB and Renault where general and meta rules have been insufficient for the dynamic of learning). The level of centralisation however does not have a clear role either on exploration or on exploitation, even if most of the case studies are characterised by decentralised knowledge. This level is most of the time more related to the historical specificity of each user in this sector.

In the case of exploitation with low exploration (as in the cases of Renault and Renault Automation, PSA and Renault Automation, BMW and Kuka), we can see that knowledge is more often tacit than codified and local, assets are difficult to redeploy, whereas rules are more generally local than general.

We argue finally that our taxonomy of knowledge and assets produced may be fruitful for a better understanding of the dynamic of firms' boundaries by trying to go deeper into the "black box" of agreements. A debate, that according to us, goes beyond a purely cognitive perspective (with only the codification issue) and beyond the TCE vision which over-estimates the political aspects such as opportunism, excluding the possibility of discovering the creation of competencies in the long run.

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# **D**anish **R**esearch **U**nit for **I**ndustrial **D**ynamics

*The Research Programme*

The DRUID-research programme is organised in 3 different research themes:

***- The firm as a learning organisation***
***- Competence building and inter-firm dynamics***
***- The learning economy and the competitiveness of systems of innovation***

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

### *Theme A: The firm as a learning organisation*

The theoretical perspective confronts and combines the ressource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human ressources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

### *Theme B: Competence building and inter-firm dynamics*

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

***Theme C: The learning economy and the competitiveness of systems of innovation.***

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

## The Ph.D.-programme

There are at present more than 10 Ph.D.-students working in close connection to the DRUID research programme. DRUID organises regularly specific Ph.D-activities such as workshops, seminars and courses, often in a co-operation with other Danish or international institutes. Also important is the role of DRUID as an environment which stimulates the Ph.D.-students to become creative and effective. This involves several elements:

- access to the international network in the form of visiting fellows and visits at the sister institutions
- participation in research projects
- access to supervision of theses
- access to databases

Each year DRUID welcomes a limited number of foreign Ph.D.-students who wants to work on subjects and project close to the core of the DRUID-research programme.

## External projects

DRUID-members are involved in projects with external support. One major project which covers several of the elements of the research programme is DISKO; a comparative analysis of the Danish Innovation System; and there are several projects involving international co-operation within EU's 4th Framework Programme. DRUID is open to host other projects as far as they fall within its research profile. Special attention is given to the communication of research results from such projects to a wide set of social actors and policy makers.

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