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Competitiveness and production networks: the case of the Argentine automotive sector

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This paper offers an empirical methodology for evaluating the development of production networks. It looks at the linkages between the flow of knowledge within the production network and the development of firm-endogenous capabilities, and applies this methodology to the Argentinean automotive industry in order to study its weaknesses and potential. The paper finds that the automotive network is partially integrated and based on incomplete interactions. In general, the firm's innovative performance is based on its own strategies and background, and the effects of a closer interaction with the network are undermined. However, this paper concludes that the network is significant for explaining the complexity of innovative activities and work organization.

1. Introduction

The goals of this paper are to discuss the conceptual foundations of vertically integrated production networks (PNW) and to develop an empirical methodology, which is then applied to the Argentinean automotive industry in order to shed new light on its weaknesses and potential.

By PNW we understand an economic space which includes an organizing firm ('core'); a group of suppliers and the interrelationships derived from purchase and sale transactions, and especially from the flow of information, 'know-how', personal experience, and knowledge circulating within the PNW through formal and informal channels.[1] Our aim is to contribute to the development of a generally applicable methodology capable of going beyond case studies and offering an overall view of the learning process inside firms; and to examine the way it is amplified and disseminated through the networks involved.

Among multiple configurations which might constitute a given network, we focus on the linkage established between the core-firm and its input suppliers, as this is key to

[1]This methodology is based on previous developments in the automotive sector (see Novick and Yoguel, 1998; Yoguel *et al.*, 2001; Novick *et al.*, 2001; Albornoz *et al.*, 2002). Throughout this paper some comparative references are made to the degree of development of the Argentine automotive network.

understanding tangible and intangible flows. We also look at the linkages between such flows and the development of endogenous capabilities within the firms. The knowledge path is critical for core-firm strategies when they compete with other networks in the market and also for the survival of the remaining firms constituting the PNW. Therefore, the network is determined by the particular relationship established between core firms (generally, final goods producers or downstream producers in an input chain) and their local suppliers, and by the competence-building process within the PNW. Thus the theoretical representation proposed here involves (i) a commercial supplier–core relationship; (ii) the development of competitive capabilities among suppliers; and (iii) the generation and dissemination of knowledge inside the PNW.[2]

The intensity of the learning processes within PNWs depends on several factors: (i) the degree of development of the suppliers' endogenous capabilities; (ii) its hierarchical structure; (iii) its degree of self-organization; (iv) tacit elements developed in different dimensions; (v) the exchange of experiences and joint projects; (v) the dissemination of information across member firms; and (vi) the interactions with companies and organizations included in the firm's production environment, which entails an increase in competence. The PNW might be considered an epistemic community (Cowan *et al.*, 2000), sharing a language and 'fragmented codified' knowledge difficult for outsiders to understand and thus perceived as tacit knowledge. The degree of network development depends on the metabolic process described by Nonaka and Takeuchi (1995), which involves different phases: internalization (transforming codified external knowledge into tacit knowledge), combination (making compatible and combining codified knowledge), socialization (combining different tacit pieces of knowledge), and externalization (codifying tacit knowledge). This process, which generates and disseminates knowledge, is influenced by the ability to absorb and generate PNW knowledge as a whole and as well as by each of its components.[3] This is the reason for

[2]The notion of the network used in this paper is different from both the concept of the cluster (Schmitz, 1995; Meyer-Stammer, 1998) and from the idea of the value chain and the global commodity chain (e.g. Humphrey and Schmitz, 2001; Gereffi, 2001), on which much ink has been spent. It differs from the notion of the cluster in that PNW representation explicitly establishes the hierarchy between firms and in that agents belonging to a network may not necessarily share the same geographic location. It differs from global commodity chains in that PNW offers a similar picture since both structures are hierarchical and the core's governance is crucial (Humphrey and Schmitz, 2000). However, it also differs insofar as the emphasis on microeconomic considerations is greater: PNW takes into account the internal organization of the firms and the way they organize work, control quality and establish training strategies. Finally, a PNW representation competes with sector-based classical analysis. On the whole, both approaches focus on the same firms. Nevertheless, such intersection is not complete: not all suppliers belong to the same sector of the core firm and, consequently, firms from the same sector may not share the same PNW. However, both approaches may be viewed as complementary. Sector-based studies identify particular firm behaviour depending on the sector. This descriptive nature is useful but it does not lead to an inquiry into the sources of the sector specificity. The concept of the PNW incorporates the knowledge dynamics which might shed light on the reasons of such specificity described by sector-based analysis.

[3]A similar approach applied to clusters has been described in Giuliani (2002). Unlike traditional

studying the individual process of creation of knowledge (innovation capability), the work organization (as a dimension through which informal knowledge is created and diffused), formal training effort (as a main channel for transmitting formal knowledge) and the linkages established among firms of a same PNW (the way formal and informal knowledge spread within the network).

Our methodology contributes to the understanding of sector's competitive weakness by identifying several elements the importance of which is not recognized either by managers of firms (especially by those of core firms) or policy makers. In the case of the Argentinean automotive PNW (APNW), the firm's endogenous competencies are high (especially that of quality) but non-systemic. Moreover, there is no association between the firm's endogenous competencies and the flow of knowledge and information between them, and the core firm is weak. The only significant influence of the core firm is with regard to the development of new products and the way that supplier firms establish their work organization. We find that the APNW is partially integrated and based on incomplete interactions and therefore synergies are weak when it comes to the competencies-building. This finding corresponds with the understanding of the weakness of the APNW in generating dynamic competitive advantages in a market that is becoming increasingly open.

The present work has been divided into four sections. The first is concerned with theoretical considerations. Initially, arguments that support the basic working hypothesis are set out. Then a representation is proposed as an approach to learning and skill-development processes in a network-dominated model. The second section then describes the methodology from which we derive the construction of a set of indicators that encompasses all the dimensions involved in the generation and dissemination of knowledge through a network. In the third section, we tackle the major results of our empirical study with a special emphasis on the degree of association among different aspects that determine the firm's competence and the linkage relevance with the automotive core firm. Finally, we state our main conclusions.

2. A methodological approach to the generation, dissemination, and appropriation of knowledge in productive networks

After assessing what a PNW means in this paper (Section 2.1), a schematic representation of the whole process inside a PNW is proposed (Section 2.2). Finally, several indicators (on which the empirical section is based) of innovative behaviour among PNW's members are discussed to account for competence development of suppliers in a PNW and the degree of dissemination between suppliers and the core-firm (Section 2.3).

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literature on this subject, the author defines the notion of the Cluster Absorption Ability, in terms of the cluster's abilities and those of its member agents to identify, assimilate, and take advantage of knowledge from external sources.

2.1 On the concept of PNW

PNW is an economic space that includes a core firm and its suppliers. This representation focuses on the interrelationships derived from purchase and sale transactions, and especially from the flow of information, know-how, personal experiences and knowledge circulating within the PNW across formal and informal channels.

The core firm is considered to be a unit of production that coordinates the intermediate goods and services purchased in the market. Suppliers may or may not share the same geographical location. Nevertheless, the nature of the linkage varies according to the origin (either domestic or international) of the intermediate goods involved. When the core firm and its supplier share the same economic space, core-supplier linkages beyond mercantile relationships are possible.

The synergy of learning processes and the fluidity and stability of its relationships characterize a PNW. Knowledge in a PNW is twofold: the development of tacit knowledge is complemented by an increasing codification that favours its dissemination through formal languages (Poma, 2000). Synergy in PNW increases the efficiency of individual firms because their capacity to promote and/or organize interactions among the different activities is carried out inside the network.

The intensity of the learning processes at PNWs depends on several factors: its hierarchical structure, the degree of self-organization, tacit elements developed in different dimensions, the depth of experience exchange of joint projects, cell-organization level, the dissemination of information across member firms, and interactions with the local environment. This is the reason for developing a set of indicators about the innovation capabilities and effort (the process of knowledge creation), the work organization and training activities, and the linkage style (within and between firm knowledge flows respectively).

Our characterization of a PNW accordingly involves (i) the existence of a mercantile supplier–core relationship; (ii) a common economic space; and (iii) the emergence and dissemination of knowledge processes inside each firm and across the different firms of the PNW.

2.2 The process involved in generating capabilities: an outline

The generation and dissemination of information and knowledge inside PNW may be seen as the result of the capabilities that arise inside supplier firms and the significance of dissemination between them and the PNW. The generation, appropriation and dissemination of specific knowledge are evidenced both at the internal level of each firm and in the flows from and to the PNW. This demands an analysis apt to distinguish the internal dynamics of each firm and the external dynamics established between the core and the rest of the PNW. In order to capture it and give a numeric evaluation, we have established a clear distinction between competence development within the companies included in the PNW, the dissemination of information, and the appropriation of knowledge by the core firm. In particular, as we establish below, our

methodology for evaluating a PNW consists in a set of indicators on the following firm dimensions: innovation capability, work organization, training efforts and linkage styles.

Two clearly distinct though interacting dimensions may be identified within each firm: its innovative capability and its prevailing type of work organization. The interrelationship between them is governed by previous knowledge and actual efforts carried out to increase their individual competencies. For this reason we consider the training efforts as a necessary condition for the development of learning processes underlying the significance of these dimensions. The network and the core firm are interconnected precisely through certain activities that we call linkage styles, which account for network's externalities and synergy. Thus, linkage styles are considered the key element in a diffused process of development that includes the organizational and technological capabilities of the firms involved.

In order to assess the significance of the PNW, let us assume that a dense and fully interactive PNW enables the emergence of a systemic dynamics in the process of generating and appropriating knowledge. The overall weakness of a PNW is necessarily reflected in the weakness of the systemic dynamics of knowledge. Thus, in a weak PNW the individual outcome of each firm—either in the sphere of its technological/organizational capabilities or in its actual mercantile performance—is the product of its particular background and individual efforts. Conversely, an integrated, fully interactive PNW logically implies a positive relationship between individual and collective performance.

If the activities of the PNW are affected by creative externalities and learning synergies, the individual performance of member firms is either discouraged or leveraged by the degree of integration and completeness of the interactions involved. Therefore, it might be deemed that a lack of relationship between the different aspects of individual performance, and between the latter and the core-firm performance, involves a synergy loss with respect to an optimal PNW in which these aspects should be highly interrelated.

From this perspective we define *density of a PNW* as the accomplishment of two main conditions:

> **Condition 1:** A high association between the dimensions determining firm-individual competencies: innovative capabilities, training and work organization.
>
> **Condition 2:** A high association between individual firms' competencies and linkage styles with the firm core of the PNW.

The next section sets forth a conceptual development of all dimensions and indicators, while Appendix 1 describes from an operational, detailed point of view the indicators involved.

2.3 Indicators of competencies and knowledge dissemination inside a PNW

As was previously outlined, our characterization of a PNW involves: (i) market and non-market relationships between the core firm and its suppliers; (ii) a common economic space; and (iii) the generation and dissemination of knowledge inside each firm and between them and the core. In this section we present the methodology used to identify the PNW firm's endogenous competencies and the linkage style. The former is estimated through four indicators measuring the cumulative innovative capabilities, the pecuniary effort in innovation, the work organization and the training efforts. 'Linkages style' captures the hierarchy and dependence inside the PNW and the knowledge-exchange mechanisms among the network's agents.

Cumulative innovative capabilities

The indicator of innovative capabilities is to a certain extent based on a tradition of recent works carried out in Argentina (Yoguel and Boscherini, 1996; Rearte *et al.*, 1997; Moori-Koenig and Yoguel, 1998; Yoguel *et al.*, 2001) and includes both intangible factors and tangible characteristics. The cross-linking of four dimensions constructs the indicator:

First, it is based on the potentialities of human resources to carry out developments which are estimated from three independent components: (a1; see Appendix 1) the ratio of workers dedicated to R&D over total workers; (a2) the ratio of highly qualified human resources (engineers and technicians) over the total number of workers; and (a3) the ratio of qualified workers devoted to research and development ('innovative qualified workers').

Second, we use an indicator that reflects whether or not the firm possesses a formal R&D infrastructure.

Third, we measure a component that accounts for 'complexity' (or diversity) in innovative activities. Its purpose is to estimate the number of areas involved in the development task for each firm considering the following alternatives: (i) product development and improvement; (ii) product adaptation; (iii) development of new processes and process improvements; (iv) new forms of distribution and marketing; and (v) the achievement of a JIT ('just in time') relationship with suppliers. Due to limitations in empirical evidence, the indicator of 'complexity' in the innovative activity does not reflect the intensity of innovations. It measures only their existence and diversity. However, the resulting complementariness between different innovations (Milgrom and Roberts, 1990) suggests that the intensity of an innovation should be positively correlated to other innovations being developed simultaneously.

Finally, a composite indicator is estimated, which accounts for the efforts undertaken in favour of quality assurance. According to this, the existence of quality sequences and standards certification practices is assessed. In other words, we quantify the importance of the rational control of quality over the production process. Thus, the quality indicator is the simple average of three components that indicate the complexity of quality control (sequence) and the relevance of external quality certifications. The

degree of complexity is determined by the number of activities involved in the process and by the estimation of 'statistical parameters in check points' that enable improvements in particular tasks (histograms, cause-effect diagram, variable-control graphs, statistical control, etc.). Besides, the external control over product quality is given by the acquisition of quality standards: ISO9000/9002 certifications and other standards are specially considered.

Since the aggregate indicator of 'innovative capabilities' takes into account all these factors, an aggregation criterion is required. An 'eventual' difficulty arises to determine it: each dimension involved should be assigned a certain weight. It may be argued, for instance, that the potential of human resources to carry out developments is more relevant than the diversity of the activities carried out.[4] However, the sensitivity analysis (following Yoguel and Boscherini, 1996) indicates that the ranking of firms according to their innovative capabilities is invariant with respect to changes in the weight of the factors included in this indicator. Thus, in order to test whether a 'subjective appraisal' problem arises or not, we compared the act of comparing the rankings that resulted from three different weights of each component. That is to say, the 'cumulative innovative capabilities' indicator was calculated in several different ways: (i) as the simple average of the values of its components (neutral indicator); (ii) as a weighted average that emphasized either work capacity (work-oriented indicator); or (iii) as the innovation complexity or diversity (complexity-oriented indicator). Firms were ranked according to their estimated innovative capabilities according to such weightings. No significant variations were observed.[5]

Pecuniary effort in innovation (PEI)

Generally, the empirical evidence does not offer robust information about the expenses devoted to innovation. Pecuniary efforts dedicated to innovation may be measured, however, through an indicator that expresses whether the firm has made purchases that directly or indirectly affect its innovative results. Such 'purchases' involve embedded technology, knowledge, expenses in R&D, organizational changes, channels, and product and/or process adaptations.

Therefore, our approximation to pecuniary effort is defined as the ratio between purchases directly associated with innovations actually carried out over the total of possible purchases. We have controlled the 'eventual' problem of how to rank 'purchases' using the same robustness method explained above: different weights for purchases yield similar rankings.

Indicator of work organization

The main assumption behind the indicator is that the emergence of codified knowledge and the appropriation of tacit knowledge through what has been called innovative

[4]This is even more arguable if the measure of complexity does not include a coefficient that reflects the 'intensity' of innovation.

[5]Therefore, we use in this work a simple average.

capabilities require an organization of work that might enhance the worker's competencies. In other words, according to this theoretical perspective the organization of work is seen as a key factor for the dissemination of the workers' tacit knowledge (Novick and Gallart, 1997; Novick, 1999).

The indicator that reflects complexity in the organization of work is a weighted average of: (i) the existence and character of cellular organization; (ii) the degree of polyvalence; and (iii) the structure of qualification. In order to estimate cell significance, three factors are assessed: (i) the percentage of workers organized in cells and the significance of the activities involved; (ii) to what extent workers determine production rhythms and quality standards, how they participate in programming or reprogramming automated machinery or in the design, improvement, and development of products and processes; and (iii) their degree of autonomy expressed in the existence of a supervisor or facilitator in the team. As regards polyvalence, its relevance in the organization of work and its degree of complexity are both considered, according to whether polyvalence/multiskilling includes several sectors within the firm and/or involves skills associated with different jobs or not.

The connection between innovative capabilities and work organization: training efforts

Up to now, it has been assumed that the development of technological competencies inside each firm in a PNW depends on its innovative capabilities and on how work is organized. In this respect, formal and informal training plays an important role in connecting both aspects. Two dimensions may be identified in this regard.

From a static point of view, the relative effort devoted to training may be identified, as well as the relationship between training, the structure of qualification and its degree of autonomy. The indicator of type of qualification defines three values according to the structure of qualification (technical professionals + technicians over total employment). By the same token, three different levels of training efforts are established and measured in percentage terms as training expenditures over effective sales. The third indicator reflects the relationship between the structure of qualification and the training effort. It involves the percentages used in the previous indicators (on the one hand, technical professional + technicians over total workers, and on the other, training expenses over sales). This indicator is expressed as a relative value. Finally, an indicator of 'autonomy' is defined according to the involvement of the headquarters in the training efforts carried out by the core in question. It is a binary indicator equal to one when the core firm does not participate in selecting the audience, the contents or the teachers involved in training.

Our second concern is the endogenous effort to harmonize the structure of qualification through training. It has been estimated by measuring whether or not less skilled workers are involved in training activities.

In order to obtain an effective estimation of training as the link between innovative capabilities and work organization, the following items have been considered: the mean qualification of workers in terms of the relative weight of professionals and technicians,

expenses devoted to training, the existence of a training structure included in the area of human resources, and the relevance of that training for less skilled workers.

Linkage styles

The analysis of the linkage styles is focused on the degree of dependence and hierarchy existing in the no-price mechanisms of exchange between the firms which are conditioned by the contractual dynamics in force and by the implicit regime of incentives. The configuration of these factors determines the structural features that define the PNW and its dynamics.

Hierarchy and degree of dependence. In order to characterize the relationships between the firms, temporal dimensions are to be taken into account as well as the vertical or horizontal relationships existing among the PNW firms and with the core firm.

When intangible exchanges are limited, the relationship between the supplier/s and the core firm(s), and hence, the total PNW dynamic, is limited to the fulfilment of the commitments and specifications established in the contract.

Medium and long-term relationships may be established only under certain special conditions, namely, when there is a long-term horizontal linkage between contractor and supplier, and when both of them participate in the design process and/or in the solution of problems. Such a relationship is known by the name of *systemic relationship* (Dussel, 1998). In this case, firms with 'stable' cooperation agreements and/or with informal exchanges in major issues are found. In the other case, there are agents who do not have any formal type of cooperation or relevant informal ties; that is, they operate in a strong relative isolation within the PNW.

The indicator we propose makes it possible to differentiate alternative linkages having an unequal degree of hierarchy. At one end, the relationships are exclusively supported by the requirement of conformity to conditions—whether agreed upon or not—with no counterpart at all. At the other end, there are bilateral agreements; and at a middle point, it is possible to identify the unilateral transfer of specific experiences and technical assistance (for instance, quality improvement techniques).

Knowledge exchange mechanisms among the network's agents. One of the differentiating elements of linkage styles is the importance of intangible assets exchanges and the terms and manners in which tangible exchanges connected with the offer of goods and services are agreed upon and programmed. Another element is related to the joint activities linked to the search for mechanisms to operate with higher relative levels of certainty in order to obtain a higher joint efficiency and rationality, above the level achievable on an individual basis. Especially in certain kinds of activities, where joint developments and proximity are needed, the information flows must be not only quantitative, but they also require a tacit knowledge. The flow and codification of such knowledge, unlike the traditional action–reaction mechanisms, imply a strong interaction among the firms.

When considering these questions as a whole, it is necessary to take into account not only the frequency of the exchanges among the firms in the network, but also the

quality and degree of importance achieved in the 'no price' relationships among them. Such factors as the type of information, the specific exchange mechanisms, the development and/or execution of joint actions, the agreements and cooperation mechanisms, and the possible transfer of technology become relevant.

The type of predominant contractual relationships is also contingent on the importance of these exchanges. However, the literature is not homogeneous with regard to the importance acquired by the contract and the regime of incentives. Williamson (1975) underlines the central role of the 'contract' and the determination of incentives as a key element for the conformation of the network. Other authors emphasize instead the role of 'mutual trust' in the development of this kind of configurations (Bianchi and Miller, 1994; Saxenian, 1994). Both positions, however, should be analyzed within the framework of past histories (path dependence), prevailing practices and the degree of development of the local milieu where the agents act.

It is within such framework that it is necessary to discuss the role of the formal or informal 'contract' model established among firms, its role in the type of linkage, and especially in the development and enhancement of no-price exchanges. Thus, for example, while in a regional agglomeration linkages generate trust–distrust relationships which regulate the exchange relationships among agents, in the case of a PNW the role fulfilled by the contract and the 'confidence' in the regulation of exchanges is less clear. While in the local system and/or cluster the absence of contracts may be the expression of a previous mutual trust creation process; in the PNW case the interpretation is more ambiguous. It may be the expression of an extreme 'dependence' model, where the core firm univocally maximizes the benefits of unilateral relationships.

In the PNW where there are contracts, their execution and contents may gradually acquire a greater accuracy on the basis of a joint learning process. In some cases, the level reached by the agents' learning leads to more accurate contents in the contracts, thus reducing the implicit uncertainty of transactions. But this joint learning may be associated in turn with a lower rate of incentives. This situation may correspond both to a unilateral maximization of benefits by the coordinating agent—reducing the transaction uncertainty and cost due to a decrease in incentives—and to joint profits obtained by the agents from the development of mutual trust relationships. In the latter case, the PNW may even operate without any formal contract, as the natural evolution of this process.

Therefore, the characterization of a PNW requires the analysis of the potential existence of contracts, their provisions and requirements, as well as the unilateral or bilateral nature of commitments, the existence of outside options, and the effects on the PNW development. From this viewpoint, the indicator evaluates the effect of these questions on the knowledge exchange mechanism.

Summing up, the linkage models in a PNW do not constitute an immutable organization form. On the contrary, there are elements that determine their profile in terms of solidity or liability. All the questions discussed above have a strong bearing on

the possibility of generating bi-directional flows in the long run and changing the terms of negotiation and the regulatory mechanisms of the relationship by all the agents in a PNW.

The development of an indicator of 'linkage styles'. The generation, dissemination and appropriation of knowledge inside each firm not only require internal training processes, a post-Fordist work organization, and the existence of formal and informal groups dedicated to various types of development, but also the possibility of further improvements from other agents and the core firm that contribute to synergize the PNW. Thus, a weighted average of non-price relationships of the suppliers with (i) the core-firm and (ii) other agents has been estimated as well.

The first indicator assesses the relevance of intra-fabric connections (from the core firm to their suppliers) and has been defined as the linear combination of six components reflecting the support given by the core firm to various skill-oriented developments: training,[6] quality assurance and work organization, development activities,[7] use of the infrastructure and laboratories at the core firm, and technology transfer.

The second indicator estimates the relevance of connections with other companies and institutions (the core firm excepted) which are evidenced in: (i) formal agreements; (ii) informal contacts and conversations about subjects that favour higher technical skills;[8] and (iii) resort to technical services provided by public or private organizations (tests, analysis and methodologies, the search for technological and market information, its processing and analysis, training seminars and courses, research and development projects).

3. Empirical application: Argentine automotive industry

This section is dedicated to an assessment of the extent to which the methodological framework works in the Argentinean automotive industry. This sector was chosen because it serves as a lights and shadows metaphor of Argentinean industrial development. The automotive evolution path correctly reflects different phases of the Argentine industrialization process from an autarchic model, the so-called Import

[6]The following topics have been considered: the extent to which the core firm influences training decisions at suppliers firms; thematic areas involved; methodologies applied; targeted audience; selection of suppliers; and ulterior feedback.

[7]The following concerns are addressed: the extent to which the core-firm takes part in product development and improvement, in product adaptation, in process development and improvement, in distribution changes, internal and just-in-time delivery (JIT), and how this participation decreases with the decreasing number of areas that receive assistance.

[8]For instance, among various alternatives, the following are prioritized: (i) merchandising strategies aimed at foreign markets; (ii) quality assurance; (iii) eventual joint ventures abroad; (iv) identification of possible partners; (v) development of joint training programs; and (vi) the possibility of undertaking joint product developments.

Substitution Model and its crisis in the mid-seventies, to the efforts to generate a more open economy (balance of payment monetary approach at the beginning of the 1980s and a currency board-based model during the 1990s) that have ended up in a balance payments crisis in 1982 and in a high currency devaluation in 2002. The automotive sector implies that several backward and forward linkages became very important for employment (5% of national employment) and GDP (7% of industrial production) and for its Foreign Direct Investment (FDI) high presence. Finally its evolution has been supported by an active public regulation and has become a reference point when discussing development strategy for Argentina.[9]

Information on the diverse issues that are involved in our methodology was collected during 2000 through a survey performed by the Industrial Studies Institute of the Universidad General Sarmiento. The construction of the questionnaire aimed at capturing tangible characteristics (such as amounts of R&D investments, work organization, job qualification, sales, organizational changes and innovation) as well as tacit elements of knowledge accumulation (informal linkages inside and outside the firms, subjective evaluation on firm's activities including training and work organization). Apart from gathering answers, personal interviews with director and/or owners of the firm were carried out in order to reinforce survey-information. Additional background was acquired from the sector chamber and national accounts.

3.1 Descriptive analysis

In Appendix 2 the main characteristics of the selected panel are outlined (the panel included seventy-five firms). The following points should be highlighted:

- Quality assurance is the clearest activities of the firm involving a weak form of innovation. All firms have made several efforts at assuring a minimum quality gap. During the 1990s, practically all restructuring has been oriented toward this single goal which aimed in turn to preserve previous market share.[10]
- The structure of firms significantly integrated by FDIs is also vital. A clear-cut

[9]Research on Argentine automobile industry was successively focused on its economic structure (e.g. Sourrouille, 1980; Roldan, 1996; Lugones and Sierra, 1998), the historical evolution of its production (Katz and Lengyel, 1996), the different behavior of the complex subsectors (Novick and Yoguel, 1998; Kosacoff *et al.*, 1999), labor relations (Catalano and Novick, 1996, 1999; Battistini, 2000) or the mechanics of production networks creation and linking (Novick and Yoguel, 1998; Yoguel *et al.*, 2001; Novick *et al.*, 2001) make a deeper analysis of the mechanisms of adaptation to the local context or hybridization.

[10]After the opening up of the market, competition imposes a high quality level in products and services. For local providers, the 'quality gap' between their products and equivalents at international markets needs to be close to 0. Thus, quality assurance becomes a necessary condition for carmaker suppliers. The opening process has been so abrupt—either regionally (Mercosur) or internationally (decreasing barriers to trade, no subsidies, and deregulation)—that 'quality' became an excluding condition for the firm's strategy.

difference may be noticed, in this respect, with the situation in the earlier 1990s, when firms of domestic capital were the most numerous and relevant.
- The different factors involved in the APNW are noticeably uncoordinated, which undermines the overall synergy of the PNW.
- The linkage style established into the APNW is weak and informal. In most cases, contracts are absent. Mostly the mercantile and impersonal relationships are the only relevant linkage for the APNW.

The evaluation of the APNW enables us to detect whether the firms involved carry out their activities at systemic levels, despite the efficacy evidenced by the final quality of their products. In other words, association indicates whether member firms make the most of the synergies involved in the PNW and to what extent they benefit them.

3.2 Econometric analysis

By using the indicators suggested above (Section 2) and by applying them to the automotive data, we can now identify which linkages are significant for the APNW and which are non-relevant dimensions for the flow of knowledge at current conditions.

The following aspects (see Section 2.2) should be assessed: (i) the level of cumulative innovative capabilities, the complexity of development activities and the development of new products; (ii) work organization; and (iii) efforts dedicated to training.

The explicative variables are derived mainly from the different components involved in relationships inside the core firm and outside it and from the pecuniary effort dedicated to innovation.

Table 1 shows the results of the econometric estimation. As a matter of familiarity we present only OLS estimations, although we have also estimated median regressions in order to avoid the problems of outliers, and the results remained the same.[11] Using the augmented regression method (see Robin, 1999), we do not detect endogeneity for the variables we have used. In the following paragraphs the most significant questions are summarized.

Estimation of cumulative innovative capabilities
Let us represent cumulative innovative capability ($IC \in [0,1]$) as follows:

$$IC_i = f(X_i, Z_i, LS_i)$$

where X_i are control variables for fixed effects such as sales, size (small, medium and large-sized enterprises) and origin of capital (OC, indicating whether it is FDI or domestic), Z_i is a set of firm indicators relevant for the PNW and LS_i represents the linkages styles.

Equation (1) attempts to estimate the innovative capabilities as a function of training, work organization (worg) and linkage styles (LS).

[11]Median regressions are available upon request.

Table 1 Econometric estimations

Equation	1. Cumulative innovative capability	2. Cumulative innovative capability	3. New products development	4. Complexity of development activities	5. Work organization	6. Training
C	0.59*	0.53*	1.04*	0.63*	0.24*	
	(4.57)	(4.11)	(4.08)	(3.73)	(3.84)	
Training index	0.11	0.05	0.07		0.02	
	(1.72)	(0.58)	(0.34)		(0.42)	
Purchase of knowledge		–0.11	–0.39		0.04	
		(–1.48)	(–1.65)		(0.73)	
Expenditures in R&D		0.17*	0.38		0.06	–0.12
		(2.47)	(1.20)		(1.10)	(–0.99)
Organizational change		0.02	–0.26		0.11*	0.28*
		(0.21)	(0.17)		(2.16)	(2.12)
Purchase of embedded technology		–0.01				0.39*
		(–0.09)				(2.21)
Monetary effort in R&D				0.33*		
				(2.49)		
Quality sequence						0.31*
						(2.42)
Cell-relevance indicator		–0.03				0.24
		(–0.34)				(1.52)
Cell-autonomy indicator		0.08				–0.22
		(1.02)				(–1.44)
Type of polyvalence		0.07				–0.12
		(1.14)				(–0.57)
Wide indicator of work organization	–0.03			–0.45		
	(–0.15)			(–1.55)		
Linkage style with core firm	–0.24	–0.11	0.80	0.51*	0.46*	0.01
	(–1.34)	(–0.46)	(1.92)	(2.17)	(3.65)	(0.01)
Size1	–0.04	0.02	–0.26	–0.10	0.11*	0.04
	(–0.48)	(0.27)	(–0.72)	(–0.76)	(2.05)	(0.27)
Size3	–0.01	0.04	–0.10	0.19	0.20*	0.08
	(–0.22)	(0.50)	(–0.72)	(1.57)	(3.18)	(0.57)
FDI	0.04	0.04	0.02	–0.02	0.01	0.07
	(0.78)	(0.84)	(0.20)	(–0.23)	(0.25)	(0.63)
R^2	0.12	0.26	0.36	0.25	0.45	0.53

*Significant at 5%.

$$IC_i = c + \alpha_1 sales_i + \alpha_2 OC_i + \alpha_3 size_i + \beta_1 training_i + \beta_2 worg_i + \phi_1 LS_i + \mu_i \quad (1)$$

These relationships are not significant. Equation (2) is an augmented version of equation (1) since it includes the indicator of pecuniary effort in R&D (PE):

$$IC_i = c + \alpha_1 sales_i + \alpha_2 OC_i + \alpha_3 size_i + \beta_1 training_i + \beta_2 worg_i + \beta_3 PE_i + \phi_1 LS_i + \mu_i \quad (2)$$

As can be seen in Table 1, its estimation shows that the expenses in R&D are positive and significant for the innovative capabilities. The lack of significance of the remaining aspects indicates a non-fully linked PNW and an innovative ability independent of the collective dynamics. The lack of significance of the other PNW dimensions would give support to the hypothesis that the innovative capabilities in this PNW are based on the individual characteristics rather than on the PNW dimensions.[12]

In order to study the generation of innovation capabilities in further detail, we have estimated separately each component.

Equation (3) focuses on the development of new products (NPD):

$$NPD_i = c + \alpha_1 sales_i + \alpha_2 OC_i + \alpha_3 size_i + \beta_1 training_i + \beta_2 worg_i + \beta_3 PE_i + \phi_1 LS_i + \mu_i \quad (3)$$

Linkages with the core-firm (LS_i) are positive but still insignificant for the development of new products. This indicates that the incidence of the APNW core-firm on the NPD does not necessarily involve a flow of knowledge inside the PNW.

Equation (4) expresses the complexity of activities devoted to development (DAC):

$$DAC_i = c + \alpha_1 sales_i + \alpha_2 OC_i + \alpha_3 size_i + \beta_1 training_i + \beta_2 worg_i + \beta_3 PE_i + \phi_1 LS_i + \mu_i \quad (4)$$

We find that for this component the relationships with the core firm are positive and significant, as well as the pecuniary effort devoted to innovation during the period in question.

In short, as regards cumulative innovative capabilities, the significance of the PNW is restricted to certain activities and to relationships with the core firm. Connections outside the PNW are not significant and confirm that an institutional complex influencing the innovative process is missing in the Argentinean industrial panorama (see e.g. Chudnovsky and López, 1996). Besides, training and work organization are not significant either. Similarly, the pecuniary effort dedicated to innovation in general is associated with the complexity of development activities, whereas expenses in R&D seem significant to account for the firm's innovative capability, besides their obvious

[12]This is new in this sector and may be explained as an effect of production restructuring and acquisitions during the 1990s (Novick and Buceta, 1997; Lugones and Sierra 1998; Motta *et al.*, 1998; Novick and Yoguel, 1998; Bastos *et al.*, 1999; Kosacoff *et al.*, 1999).

causal effects. Therefore, putting equations (1–4) together and using conditions 1 and 2, for the density of the PNW, we may conclude that PNWA is weak for most individual performances.

Work organization
As suggested by estimating equation (5):

$$\text{worg}_i = c + \alpha_1\text{sales}_i + \alpha_2\text{OC}_i + \alpha_3\text{size}_i + \beta_1\text{training}_i + \beta_3\text{PE}_i + \phi_1\text{LS}_i + \mu_i \qquad (5)$$

'work organization' generally is positively and significantly associated with the variable that expresses relationships with the core-firm and also with specific expenditures in organizational change. It should be highlighted that in this respect size appears to be significant. In big firms work tends to be increasingly organized in a cell-based pattern, workers show higher polyvalence and the whole hierarchy is more horizontal.

Training inside individual firms
Equation (6) shows a positive and significant association between efforts in training and some elements in the EPI: organizational change and the purchase of embedded technology. Internal quality assurance (quality sequence) is significant to account for training inside individual firms belonging to the APNW. Once again, this equation confirms that the remaining dimensions do not play a significant role:

$$\text{training}_i = c + \alpha_1\text{sales}_i + \alpha_2\text{OC}_i + \alpha_3\text{size}_i + \beta_2\text{worg}_i + \beta_3\text{PE}_i + \phi_1\text{LS}_i + \mu_i \qquad (6)$$

4. Concluding remarks

In this paper we have developed, first, a framework which aims at investigating the generation of knowledge circulation inside a PNW. Second, we have applied this methodology in order to reach a better understand of the workings of the Argentinean automotive industry.

The results show that in the APNW some significant relationships may be established between the core firm and the remaining firms in the PNW (innovative complexity activities and work organization). This indicates a vertical flow of knowledge inside the APNW. The lack of significant relationships between innovative capabilities, work organization, and training—which has been identified as a vehicle for knowledge inside firms—weakens the virtuous character of the APNW and suggests that it may be considered partially integrated and based on incomplete interactions

The weak APNW's density is reflected in the fact that each firm's innovative performance is firmly based on its own strategies and background, and that the effects of a closer interaction with the remaining firms are undermined.

The core firm imposes conditions to acquire the intermediate goods it needs from the local market. This is why relationships with the core seem so relevant for various activities carried out by local firms. Within the framework of an open market in which the firms that integrate the APNW compete at international market prices, these

conditions imply that the output of individual firms should be close enough to the 'state-of-the-art'. Hence the significance of quality highlighted above. Therefore, quality determines a nexus 'core-firm-remaining firms' that may be assimilated into the results obtained in this study. Besides, individual pecuniary efforts are significant for all the dimensions considered in the APNW. Additionally, we find that size is insignificant for innovation capabilities but it is significant for work organization: a given big firm's work tends to be increasingly organized in a cell-centred pattern. Workers show higher polyvalence and the whole hierarchy is more horizontal.

Finally, the significance of density in the PNW implies a new concern for industrial policies and proposals. The possibility of expanding the market horizon of the APNW and attaining a higher international integration certainly depends on promoting the dissemination of knowledge, connecting work organization and creativity at individual firms, and ensuring that training is efficiently associated with the acquisition of potentially wasted knowledge inside the PNW.

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Appendix 1. Methodology

This appendix describes how the following indicators are estimated: innovative capabilities, work organization, efforts devoted to training and associated with the development of internal skills, 'linkage styles' that account for the relationships of network firms with external agents and with the core firm.

A. Development of endogenous competencies

A.1 Innovative capabilities

(a) *Potential human resource capabilities to carry out developments*:
(a1) *ratio of workers devoted to R&D over the total number of workers employed*: the simple ratio between both aggregates is estimated.
(a2) *ratio of workers with a high relative qualification* (engineers and technicians): the ratio between this aggregate and the total number of workers formally devoted to R&D is estimated. The indicator is equal to 1 if this ratio is greater than 30%, is equal to 0.5 if this percentage lies between 20 and 30%, is equal to 0.25 if the percentage is greater than 0 and less that 20%, and is equal to zero in the remaining cases.
(a3) *ratio of highly skilled workers devoted to R&D ('innovative skilled workers') over total employment*: the indicator is equal to 1 if this percentage is greater than 4%, is

equal to 0.5 when this percentage is greater than 2% and less than 4%, and equal to 0 otherwise.

(b) *Existence of a specific infrastructure (R&D laboratories dedicated to create and/or adapt new developments)*: the indicator is equal to 1 when a formal infrastructure exists and otherwise is equal to 0.

(c) *Development of new products*: this indicator is the ratio between the weight of new products introduced from 1995 onwards over the total turnover in 1999.

(d) *Relevance and complexity of development activities*: this indicator is defined as a ratio between the quantities of areas involved by the development activities over the following areas considered: product developments and improvements, process developments, process improvements, new distribution and marketing methods, and internal just-in-time.

(e) *Level of quality assurance*: this aggregate indicator of quality assurance is the weighted average of the following factors:
(e1) *Sequence (weight = 0.30)*: it is equal to 1 if the firm uses control worksheets and estimates 75% of the possible statistical parameters (frequency distribution, histograms, cause-effect diagrams, variable control graphs; statistical control of attributes); it is equal to 0.50 when the firm estimates less than 75% of the statistical parameters; and is equal to 0 when the company does not use control worksheets.
(e2) *Quality certification (weight = 0.70)*: a simple average is estimated to reflect the existence of ISO9000 certification (values 0 or 1) and an indicator is computed to reflect the number of standards considered (number of standards above 3).

A.2 Work organization

This indicator is a simple average of the following factors:

(a) *Percentage of workers organized in cells*: the simple ratio is estimated.

(b) *Relevance of the cell*: this indicator is equal to 1 when cell-workers participate totally or partially in determining production rhythms, establishing and controlling quality standards, programming or reprogramming machinery, designing, improving or developing processes or products; the indicator is equal to 0.6 if less than 80% of the workers are involved in such activities and equal to 0.3 when 60% (or less) of the workers are involved.

(c) *Cell autonomy*: this indicator is equal to 1 when a supervisor and a facilitator are included in the team; it is equal to 0.5 if only one of them exists, and equal to 0 when the cell has neither of these functions.

(d) *Relevance of polyvalence*: this is indicator is equal to 1 if polyvalence is an important skill for the work organization and 0 otherwise.

(e) *Extension of polyvalence*: this indicator is equal to 1 if polyvalence requires skills from one sector exclusively and 0 otherwise.

B. Training efforts

B.1 Type of qualification
The indicator is equal to 1 if the number of professionals and technicians in the firm is greater than 15%; it is equal to 0.5 when their number is greater than 5%, and is equal to 0 in the remaining cases.

B.2 Percentage of training expenses with respect to total sales
This indicator equals to 1 if this percentage is greater than the average; it is equal to 0.5 when this percentage is in the neighbourhood of 10%, and is equal to 0 in the remaining cases.

B.3 Participation of less skilled human resources in training
This indicator is equal to 1 if this percentage is greater than al 60%, and is equal to 0 in the remaining cases.

B.4 Existence of a distinct structure within the area of human resources
This indicator is equal to 1 when a separate area exists and otherwise is equal to 0.

C. Exchange of knowledge with other agents outside the network and with the core-firm

C.1 Agents outside the network

(a) *Formal agreements*: this indicator is equal to 0 if the firm has not signed formal cooperation agreements. Its value is 0.5 when the firm has formal cooperation agreements covering at least one of the possible areas (merchandising, input purchase, technology purchase, training, and exports). It is equal to 0.75 when agreements covering two areas exist and equal to 1 when the agreements cover at least three areas. The underlined hypothesis for this component is that the possible areas are uniform form the point of view of knowledge transmission
(b) *Informal connections with other agents outside the PNW*: the number of different issues included in possible exchanges with other agents is considered, as well as the frequency of such interactions. Among possible issues, a group of topics of greater relative complexity is selected among those having a relative weight of 1 when the alternatives of the firms were considered (the possibility of carrying out joint business, possible partnership, shared training programs, shared product and process developments, problems associated with quality management). A weight of 0.5 is assigned to informal talks about business carried out within the framework of Mercosur and about automotive regulations for the year 2000. A weight of 0.25 is assigned to informal talks about core firms' demands, merchandising strategies for the domestic market, and topics related to the sector's chamber. Finally, a weight of 0 is assigned to the remaining alternatives (conditions at the country, financing, labour problems and others). The aggregate obtained for each firm is divided into the maximum possible amount (7.5) so as to parameterize factors. The result thus obtained is then multiplied by the periodicity of connections: the factor is equal to

1 when daily or weekly contacts occur; it is equal to 0.5 when monthly contacts occur, and equal to 0.25 if contacts are merely sporadic. These informal linkages may be very important in the PNW when they are referred to those issues linked to endogenous development competencies.

(c) *Institutions outside the network*: the values of this indicator lie in the interval [0,1]; it is equal to 1 when the firm resorts to other institutions that: (i) perform tests; (ii) provide analysis and methodology; (iii) search for technological and market information and also process and examine it; (iv) provide training seminars and courses; and (v) carry out research and development projects. The remaining values are defined as the ratio between effectively realized connections and total possible connections.

C.2 Inside the network
This indicator involves six different components:

(a) *Participation of the carmaker in training activities*: this indicator lies in the interval [0,1]. Its maximum value corresponds to a car maker that has actual influence on decisions about training, thematic areas involved, methodologies selected, target audience, trainers' selection, assessment and other related issues. Its value decreases with the decreasing number of assistance areas.

(b) *Intensity of technical assistance for quality and work organization*: this indicator is equal to 0 if there is no assistance; it is equal to 1 when technical assistance is provided for all the alternatives involved, and is equal to 0.3 for each element involved (quality improvement techniques, product development and design, work and production organization).

(c) *Core firm support for development activities*: this indicator adopts values in the interval [0,1]. The maximum value (1) is assigned when the carmaker takes part in product development and improvement, product adaptation, development or improvement of new processes, distribution transformations, internal JIT and client–supplier relationships. Its value decreases with the decreasing number of assistance areas. In this sense, the indicator is a ratio between the alternatives for which the firm receives support and the total number of alternatives considered.

(d) *Use of the core firm's infrastructure and laboratories*: this is indicator is equal to 1 if the provider uses the core-firm's laboratories and is otherwise equal to 0.

(e) *Technology transfer*: this dimension involves the transfer of organization and quality standards, process and product technologies, and work organization methods. This indicator is equal to 0 if there is no transfer from headquarters; it is equal to 0.5 when there is transfer from headquarters, and equal to 1 when there is transference from carmakers and/or technology providers, etc).

Appendix 2. Information

The main features of the surveyed panel are presented, comprising structural characteristics and the main elements involved in knowledge generation and dissemination.

The seventy-five firms in the panel represent an important part of the total number of carmaker suppliers: 54% are foreign companies, which cover approximately 70% of the purchases. This high proportion of FDI firms is the result of the strong industrial restructuring process that occurred during the 1990s. While among FDI firms big-sized (annual sales above 19 million pesos) and medium-sized (sales between 3 and 18 million pesos) companies prevail, small-sized firms (annual sales below 3 million pesos) prevail among national ones. Almost two-thirds of the FDI firms have been established through the purchase of previously existing firms. On the contrary, in the case of national firms, this share is only 9%. This indicates that a significant portion of foreign investment was focused on the purchase and restructuring of previously existing firms. The low effort of FDI firms towards establishing new plants is evidenced in the fact that their relative weight is the same when FDI firms are compared with national firms (15% and 11%, respectively).

In the current scenario, quality assurance is a necessary condition for suppliers in this sector. This is evidenced not only in the all-pervading requirement of ISO standards (72%) but also in more complex standards required by carmakers. Besides, there is a generalized effort devoted to training. The relevance of training activities is closely linked with quality assurance. However, the non-systemic and disorganized character of individual strategies is evidenced in the weak connection between training efforts and the remaining dimensions examined: cumulative innovative capabilities, complexity of work organization, and pecuniary efforts devoted to innovation.

Thirty-five percent of the firms surveyed have formal R&D laboratories. However, the existence of laboratories is not associated with the number of firms following ISO9000 standards:

Seventy-two percent of those that have formal laboratories and 68% among those that lack a formal lab. The development of new products (NPD) is slightly related to the carmaker participation in product development. Thus, for example, in the case of firms where carmakers have no influence on product development (60% of the panel), new products are highly significant only for 36.7% of the companies involved. In the remaining cases, the influence of the carmaker is significant for developments, and in approximately two-thirds of the cases examined, new products are very important.

Around one-quarter of the firms examined have no cell organization. For 23% of them cells are slightly significant, for 27% they are relatively significant and for 25% they are very significant: 70% of the work force is organized in cells. Cell organization and quality assurance are highly dissociated. Thus, the percentage of firms following ISO9000 standards is independent of cell organization (92% of non-cell-organized firms follow these standards whereas 80% of cell-organized firms observe them).

Besides, the relevance of cell-organization is not associated with the existence of independent training structures. This fact indicates that there is no correlation between work organization and training. Likewise, cell organization does not depend on the size of the firm: approximately two-thirds of the firms in the panel have their own training structures, independently of their size.