The automobile technological systems. An empirical analysis of four European countries*

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Abstract

The aim of this paper is to study the automobile industry of the most important European countries (France, Germany, Great Britain and Italy) from a sectoral, system perspective. The main relationships within and between the building blocks constituting the automobile technological system are mapped and evaluated, both in cross-sectional and in temporal terms. The importance of the sectoral TS as the unit of our analysis appears evident at both levels. Some general sectoral properties emerge, which however hold in the four countries to a different extent, thus suggesting how the institutional set-up works as a differentiating element. A sustained process of change in the various elements of the automobile TS is detected, nevertheless resulting in a relatively stable path of development. The countries considered reveal different patterns of motor vehicles trade specialisation in different geographical areas, with changes over time. Also foreign direct investments show the existence of very different trajectories and outward/inward balances.

1 Introduction

Although its meaning is not completely unambiguous, the concept of globalization seems to have become nowadays a useful catchword to describe the present phase of high international integration (OECD, 1992). Not only has the volume of exchanges between countries increased, but also new channels have been established to diffuse goods, information and knowledge around the world. This is also true with respect to technological change. The fact that innovation can be produced and appropriated in locations other than those where firms reside, by exploiting a scientific knowledge base which spreads across countries, induces to think in terms of 'techno–globalism'. Simultaneously, the innovative relationships established within and between different economic sectors, either deliberately (i.e. in terms of technological transfers) or naturally (i.e. in terms of spillovers), have largely increased.

These phenomena have raised the problem of how to study the structure of a certain industry and its actual degree of 'intersectoralisation' and 'internationalisation'. In this paper we argue that a sectoral interpretation of the concept of technological system (Carlsson and Stankiewicz, 1991) can be usefully adopted in pursuing this objective.

Indeed, the spatial and interindustrial extension of the techno-economic relationships that make up for a technological system (TS) are two key elements in evaluating the structure of one industry and the nature of the structural change it eventually undergoes along time. Furthermore, when it is accompanied by an institutional kind of analysis, the concept of sectoral TS allows for the integration of the domain of the institutional set-up — that regulates, constrains and stimulates the production and the innovation processes of the relative organisations (firms, research institutes, associations, etc.) — with the relevant techno–economic relations within a coherent framework.

The argument we put forward appears particularly relevant in the case of the automobile industry. On the one hand, its 'chain–value' appears to be one of the most interrelated, when producer–users and producer–producer relationships are considered, and when the role of institutional regulations is clearly recognised, both as innovative constraints and as innovative incentives. On the other hand, this sector is one in which international relationships are so widespread to identify a truly transnational, if not even a global kind of TS.

This paper aims at empirically defining and evaluating the sectoral technological systems of the automobile industry with respect to the most important European countries (France, Germany, Great Britain and Italy). In particular, using data on production and innovation intraindustry–intersectoral flows, along with data on bilateral trade and foreign direct investment, we will try to map the relevant relationships within the main building blocks constituting the automobile TS. In so doing, we intend to furnish a novel viewpoint with which we will try to make a direct appreciation of the phenomena linked to (or determining) the evolution of the automobile industry, such as, for instance, the degree of decentralisation in production, at both

national and international level, and the relevant user-producer linkages.

The paper is organised as follows. In paragraph 2 the extension of the automobile TS is defined. Its peculiar dimensions are then analyised: the industrial structure and interactions (Par. 3), the innovative activities (Par. 4), and the international relationships (Par. 5). Paragraph 6 concludes.

2 The extension of the automobile technological system

As we said already said, in this paper we are interested neither in an industrial nor in a organisational analysis of the automobile industry, for which there is abundance of literature. We want instead to present a rather different angle from which to look at it. Indeed, what we propose here is to analyse the automobile TS, which is constituted by the clustering of the techno–economic activities of the relevant actors, and therefore is quite different in its extension from the automobile sector itself.

The aim of this paragraph is to define the domain of such a TS. The way we intend to do it is by referring to the extent to which the automobile firms interact and enlarge their relationships with other organisations of the economic system. Therefore, we will refer to the huge and varied literature on the institutional analyses of techno–economic relationships which goes under the main heading of national systems of innovation/technological systems (e.g. Lundvall, 1992; Nelson, 1993; Carlsson, 1995; De Liso and Metcalfe, 1996; Edquist, 1997; Leoncini, 1998; etc.).

In particular we will consider, on the one hand, that part of the literature on technological systems that refers to sectoral or industrial specifications. This approach differs from others that refer explicitly to the geographical extension of the set of institutions supporting, shaping and determining the rate and direction of techno–economic activity (Lundvall, 1988, p. 10; Nelson and Rosenberg, 1993, p. 3). Indeed, although the relevance of the institutional set-up seems to 'constrain' the vision of the system considered, and hence to force a national (or regional) view of these kinds of relationships, a sectoral approach is also extremely relevant in understanding technological change.

On the other hand, in our analysis we will also consider some other contributions which refer to the importance of the clusterisation of techno–economic activities.[1] Indeed, firms and other institutional actors are linked by different kinds of interactions (such as, for example, user-producer and input–output relations) and constitute networks which are reducible neither to the industry nor to the nation level. Although both levels are liable to be appropriate dimensions for an industry such as motor vehicles, whose actors are surely national champions, it also true that they extend their field of action in other industries too, both indise and outside

[1]Such as Carlsson and Stankiewicz (1991). See also, in another but related field, Hughes (1989).

their own countries.[2]

Our starting point is therefore the idea that there exists a 'sectoral' TS for the automobile industry, which has an interindustrial dimension that is, for some aspects, bigger than that of the nation, and for some other a smaller one. The definition of the boundaries of the automobile TS thus becomes a very important issue and cannot be resolved with an *ad hoc* definition.[3] Indeed, it is crucial in order to identify the domain within which the main institutional and techno–economic relationships occur and should therefore be preliminary to the analysis of the nature of the relevant actors and the kind of clustering they constitute.

In this paper, we will therefore try to determine the extension and the characteristics of the automobile TS for France, Germany, Great Britain and Italy, by looking at three interrelated aspects: the type and intensity of the industrial relationships, the nature and the map of the innovative interactions, and the structure and the direction of their international extension. Indeed, these are three important dimensions to understand how different institutional arrangements among actors generate different techno–economic performances in the automobile industry. This is possible essentially because this particular TS is constituted by few big actors acting contemporarily at a supranational–regional level, but also with a relevant intra–national focus as far as the main techno–economic activities are concerned.

3 The industry side

This paragraph is devoted to the analysis of the automobile TS from an industry perspective. First, through data of general nature, we will briefly sketch some features of its relative weight within the European Union and of its structure (Paragraph 3.1). As the literature about this topic has become really massive, the picture we provide is deliberately not very detailed. We will rather focus on relational kind of aspects, for which the analysis is not yet fully developed. More precisely, by means of input–output techniques, we intend to investigate the role of the surrounding industrial set-up for the material acquisitions and diffusions of the automobile sector (Paragraph 3.2). In so doing, we will be able to infer and analyse how the different institutional arrangements of the investigated countries are able to influence the establishment of different patterns of interactions among those actors which make up for its chain-value.

Preliminarily, it must be stressed that, both in the present and in the following sections (4.2 and 4.3), our analysis has been constrained by the availability of comparable input–output tables and innovation data for the four investigated countries. Some specific years and sectoral

[2]Obviously, there are not very clear cut distinctions, and, as Carlsson and Stankiewicz (1991, p. 111) point out, their notion of TS and that of NSI are due to nearly coincide if the TS is given a national dimension.

[3]These problems apply, though in a different way, also to national TS. See Leoncini and Montresor (1999a) for an investigation of the extension of a group of national TS.

disaggregations had therefore to be chosen. However, the structural nature of the relevant data allows us to extend the relative results at least to a certain extent.[4]

3.1 General outlook

This section aims at giving a very brief and idiosyncratic picture of the European automobile industry, with a particular emphasis on the four countries that are the focus of this paper (France, Germany, Great Britain and Italy). As we have already said, we will limit ourselves to a very general overview for at least two reasons. On the one hand, the literature on the issue is really massive, and it is not our aim to replicate existing analyses. On the other hand, the declared intent of this paper is quite circumscribed, as the focus is on relational (i.e. interactive) aspects. Accordingly, at this stage, we will analyse few overall data, in order to better understand which are the problems at stake in dealing with the kind of empirical analysis we intend to pursue.

First, we will only consider ten European producers (BMW, Fiat, Ford, General Motors, Mercedes, PSA, Renault, Saab, Volkswagen and Volvo) and exclude the other brands that they own in different ways. Second, in this section we will consider only production in West–Europe and leave out the volume of production made elsewhere by these ten producers. This is because we are interested in the patterns of production that the big manufacturers implement in their home country and in countries with comparable techno–economic conditions. Third, we will mainly refer to some recent years for which we have sufficiently detailed data. In spite of these *caveats*, some facts are quite relevant for our analysis.

Table 1: Motor vehicles production in the European Union

	1995	1996	96/95	1997	97/96	1998	98/99
Cars	12,636,067	13,061,348	3.40%	13,451,272	3.00%	14,510,472	7.90%
Vans	1,318,462	1,393,245	5.70%	1,570,265	12.70%	1,675,315	6.70%
Trucks	348,577	310,204	-11.00%	334,562	7.90%	379,094	13.30%
Buses	30,519	32,001	4.90%	36,672	14.60%	35,397	-3.50%
Total	14,333,625	14,796,798	3.20%	15,392,771	4.00%	16,600,278	7.80%

A first observation has to do with the large weight recently acquired by the sector in the European market. Total production in the European Union shows an increase from almost

[4]In the case of Italy, for example, comparable tables are only available at current prices, and for 1985 only. Moreover, in the case of Germany, differently from the rest of the countries, the motor vehicles sector comprehends also residual transports equipment.

14 million vehicles in 1995 to 16 millions in 1998, with an increasing rate of change (Table 1). Indeed, although the production of cars has witnessed a doubling of its rate of change in 1998, favourable elements have to be considered, such as the well known policies of State aid to consumers (via scrapping schemes). Furthermore, let us observe that the extent of the variations is different for different classes of vehicles, and that, for example, commercial vehicles show more marked cyclical variations.[5]

Table 2: New car registrations in the European Union

Country	1990	1995	1996	1997	1998
Belgium	473.506	358.868	397.359	396.240	452.129
Denmark	80.654	135.773	142.430	152.084	159.773
France	2.309.130	1.930.504	2.132.091	1.713.030	1.943.553
Germany	3.349.788	3.314.057	3.496.320	3.528.179	3.735.987
Greece	115.480	125.023	139.821	159.867	180.145
Ireland	82.584	86.959	115.199	136.662	145.704
Italy	2.307.055	1.731.747	1.732.198	2.403.744	2.374.747
Luxemb.	38.422	28.029	29.980	31.418	35.928
The Neth.	502.627	447.942	471.989	478.290	543.067
Portugal	210.924	201.471	217.910	213.636	248.398
Spain	988.170	834.369	910.928	1.016.383	1.192.843
G. Britain	2.008.934	1.945.366	2.025.450	2.170.725	2.247.403
Austria	288.618	279.610	307.645	275.001	295.865
Finland	139.095	79.890	95.830	104.507	125.751
Sweden	229.941	169.756	183.820	225.263	253.430
Total	13.124.928	11.669.364	12.398.970	13.005.029	13.934.723

A second set of interesting observations comes from the analysis of the registrations of new passenger cars in the EU (Table 2). Indeed, the four biggest markets (France, Germany, Great Britain and Italy) accounts for around three quarter of the total registrations of new cars, with a very slight decrease from 1990 (76%) to 1998 (74%). Their time patterns are however quite different. In fact Germany and Great Britain show a steady increase over the last decade, which is counterbalanced by the decrease of France and the substantial stability of Italy. In interpreting these data, let us remember that these two countries have experienced, in different

[5]In what follows, the terms motor vehicles and automobile sector will be meant as equivalent and used interchangeably.

times, State funded scrapping schemes which contributed to smooth the decline. Such a policy worked better in Italy probably because of the older age of the car stock. Indeed, in 1997 new car registrations in Italy increased by 38.8%, while one year before in France the increase was 'just' 10.4%. Spain is the only other European market to overcome the threshold of one million new cars registered.

A third observation concerns the spatial concentration of car producers (Figure 1). Germany (with around 5 million cars produced) and France (with slightly more than 2.5 million cars produced) are the biggest producers, accounting for half of total European production. They are followed by Spain (15%), which has only one national producer (Seat, owned by Volkswagen), and by the other two big European producers, Italy and Great Britain, with almost the same share (around 11%). Finally, Belgium is the first largest producer (8.5%) with no national car manufacturers.

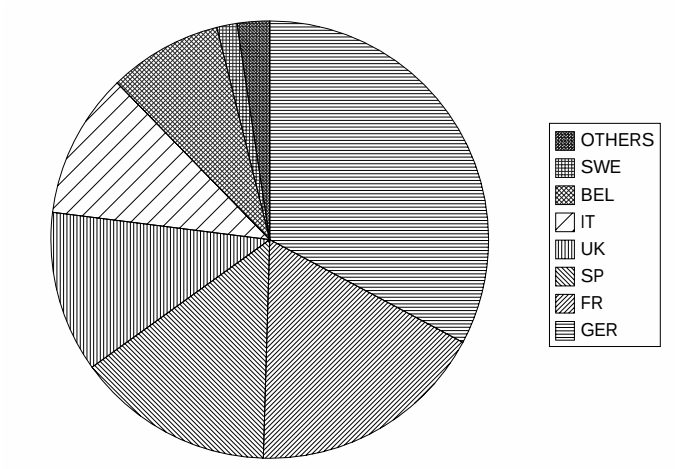

Figure 1: Car production in Europe by country (1995)

A final aspect has to do with the geographical decentralisation of the sector. The data on production by plant location (Figure 2), for example, show how almost all the car manufacturers privilege their home nation for production, with percentages clearly higher than 50%. However, some marked differences emerge. Fiat Mercedes and Saab, for example, show the highest percentages (above 80%). BMW has its production split almost equally between Germany and Great Britain, due to the acquisition of Rover. Ford appears to be the only truly multinational producer. In fact, having split its European operations equally among Germany and Great

Britain, Ford has no 'national home–base' from which to exploit particular techno–economic advantages.[6]

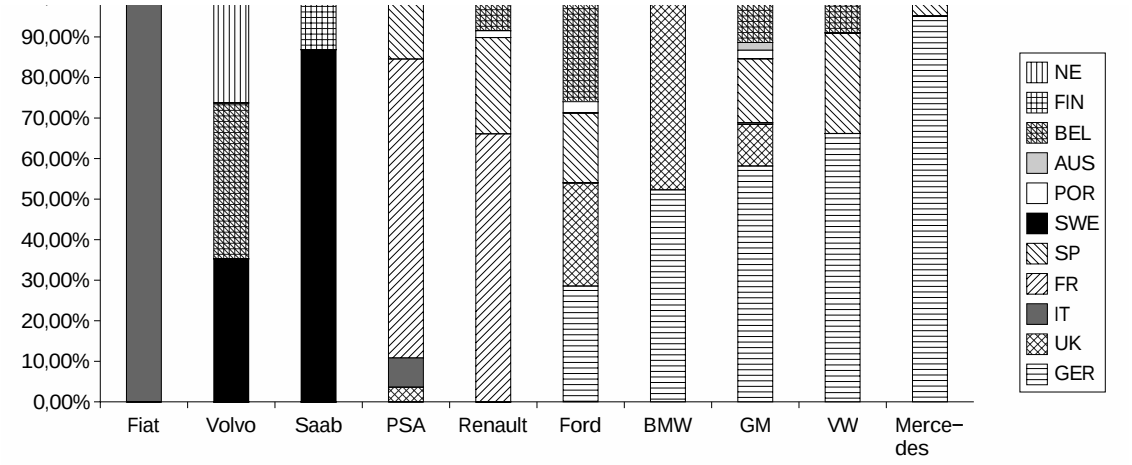

Figure 2: Car production by plant location (1995)

According to these preliminary figures, therefore, contrasting evidence emerges with regard to the role of globalization in shaping the main relationships within the automobile sector. Hence, we will now dig a little deeper in order to better qualify the extension and main characteristics of the automobile technological system.

3.2 Backward and forward linkages

An important aspect to be dealt with for a deeper industrial analysis of the automobile TS is that of its material intersectoral relationships. Although limited to intermediate goods transactions, backward and forward linkages indicators are extremely helpful in this respect. As it is well known from the input–output analysis, these indicators measure the role that a certain sector has in stimulating the production of the other sectors, respectively, from a demand (backward) and a supply (forward) perspective.

More precisely, the backward linkages indicators measure how important is a certain sector in terms of what it acquires from the other sectors of the economy (i.e. they describe the

[6]This picture is further confirmed if Volvo, which has recently been acquired, is also consolidated into the Ford figures.

material transactions of a sector with the rest of the economy from an input perspective). Two backward linkages indicators are available: *direct* and *total*. The first one accounts only for the acquisitions made by one sector from the others to obtain its immediate inputs. Analytically, the indicator of direct backward linkages (DBL) is given, for a generic sector j, by the correspondent sum by column of the input coefficient matrix, $\mathbf{A}$:

$$DBL_j = \sum_i a_{ij}$$

where a_{ij} is the generic element of $\mathbf{A}$, defined as $\mathbf{A} = (\mathbf{X})(\hat{\mathbf{x}})^{-\mathbf{1}}$, where $\mathbf{X}$ is the intersectoral production matrix, while $\hat{\mathbf{x}}$ is the diagonal vector of total sectoral output. Accordingly, $0 < DBL_j < 1$.

The total backward linkages indicator (TBL) refers to both the direct and indirect acquisitions (i.e. in subsequent production rounds) that a certain sector makes from the others. Formally, for a generic sector j, it is given by the correspondent sum by column of the Leontief inverse:

$$TBL_j = \sum_i \alpha_{ij}$$

where α_{ij} is the generic element of the Leontief inverse, $\mathbf{L}$, defined as $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$, where $\mathbf{I}$ is the identity matrix.

In addition to backward linkages, forward linkages indicators can also be defined, which measure the role of a certain sector for the acquisitions of the others (i.e. they indicate how important is a sector for the rest of the economy from an output perspective).

Similarly to the backward linkages indicators, also forward linkages ones can be either *direct* or *total*. The former, which still refer to the output that a certain sector directly provides to the others (DFL), is given by the sum by row of the output coefficient matrix, $\mathbf{A}^*$. For the generic sector i, it is defined as:

$$DFL_i = \sum_j a^*_{ij}$$

where a^*_{ij} is the generic element of $\mathbf{A}^*$, defined as $\mathbf{A}^* = (\hat{\mathbf{x}})^{-\mathbf{1}}(\mathbf{X})$.

The total forward linkages indicator (TFL), which again measures the importance of a certain sector in terms of the output that it provides to the others, both directly and indirectly, is given by the sum by row of the 'output' Leontief inverse, $\mathbf{L}^*$. Analytically, for the generic sector i it s given by:

$$TFL_i = \sum_j \alpha^*_{ij}$$

where α^*_{ij} is the generic element of $\mathbf{L}^*$, in turn defined as $\mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-\mathbf{1}}$.

Coming now to the calculation of the four indicators for the automobile sector of the countries considered (Table 3), some particular methodological choices have been made. The years

of reference have been selected on the basis of the availability of comparable I–O tables (DSTI (STAN, I–O), 1994). Their matching has brought us to work out the previous indicators with respect to a 30 sectors disaggregation (see Appendix A.1).

Some of the facts we infer from the results are quite intuitive. For instance, being car construction a scale intensive sector, the backward linkages indicators are systematically higher than the forward linkages ones, both direct and total.

However, two interesting facts emerge. First of all, Germany and France, two countries whose national TS can be shown to be the most connected of the four (Leoncini and Montresor, 1999b), are characterised by the highest values, in particular as far as the backward linkages indicators are concerned. The motor vehicle sector, therefore, contributes to shape a more systemic environment.

Table 3: Motor vehicles backward and forward linkages

	Backward linkages					**Forward linkages**				
France	1972	1977	1980	1985	1990	1972	1977	1980	1985	1990
Direct	0.54	0.52	0.51	0.50	0.48	0.20	0.18	0.18	0.18	0.18
Total	2.04	1.96	1.92	1.88	1.85	1.28	1.24	1.23	1.23	1.23
Total/Direct	3.78	3.77	3.76	3.76	3.85	6.40	6.89	6.83	6.83	6.83
Germany		1978	1986	1988	1990		1978	1986	1988	1990
Direct		0.52	0.54	0.55	0.53		0.22	0.23	0.23	0.22
Total		2.02	2.03	2.04	1.98		1.32	1.33	1.32	1.30
Total/Direct		3.88	3.76	3.71	3.74		6.00	5.78	5.74	5.91
G. Britain		1968	1979	1984	1990		1968	1979	1984	1990
Direct		0.66	0.42	0.40	0.43		0.31	0.18	0.20	0.23
Total		2.42	1.80	1.69	1.78		1.49	1.28	1.30	1.38
Total/Direct		3.67	4.29	4.22	4.14		4.81	7.11	6.50	6.00
Italy				1985					1985	
Direct				0.44					0.20	
Total				1.78					1.25	
Total/Direct				4.04					6.25	

Second, the ratio between total and direct indicators is higher if evaluated for the forward linkages than for the backward ones. This indicates that the present sector is characterised by downstream relationships which are more complex and pervasive than the upstream ones. This is more true for Italy, and more in general for Great Britain, where this ratio for the backward linkages is the highest.

Indeed, the British automobile TS seems to be the only one in which the sector reveals a structural kind of change. The values of both types of indicators tend to decrease along time (apart from the starting period), differently from the other countries, where they remain more or less stable. Different interpretations can of course be put forward to explain this evidence. Among the others, the effects of an increase in the internationalisation degree of the same sector along the considered period seems to be confirmed by the fact that the indicators are build up on total matrices, including both internal and imported production.

4 The innovative side

Although the economic relationships we have previously observed are very important to identify a TS, their innovative counterpart (i.e. the innovative sub–system) constitutes its core. Accordingly, in this paragraph a thorough analysis of the innovative structure will be provided. First of all, we will detail the main indicators of the innovative efforts of the automobile TS, that is, their R&D expenditure and patenting activity. Subsequently, we will evaluate the techno–economic interrelationships of the TS by analysing the innovative pervasivity and dependency of the relative sector, and by mapping the network of their relative innovation flows.

4.1 R&D and patents

As it is well known, although with some *caveats*, R&D expenditure and patents can be utilised, respectively, as input and output indicators of the innovative activity.[7] Accordingly, they allow us to track down how the different arrangements of each TS are reflected into its technological performance, both in terms of incentives and efficiency. Indeed, on the one side, the level of R&D expenditure is likely to be correlated to the perceived market possibilities open to the various firms. While the translation of purely technological activity into innovation, and hence into effective techno–economic performances, can be approximated by the level of patenting activity (e.g. by patents count).

As far as the R&D expenditure is concerned, we do not want to elaborate on well known features of the innovative performances of the four TS investigated. On the contrary, as we have already done for the industry side, we will highlight few idiosyncratic data in order to show some peculiarities which are useful for our particular discussion.

At the outset, let us observe how, along the chosen period, the R&D expenditure in this sector has substantially increased its weight in absolute terms. In particular, from 1973 to 1980 it has undergone a steady increase (DSTI (STAN, Anberd), 1994). If 1973 is made equal to 100,

[7] It is not the aim of this paper to discuss in deep the pros and cons of these innovative proxies. For more details, see, among others, Patel and Pavitt (1995).

in 1980 R&D expenditure was 275, with the highest and the lowest values for Germany (359) and for Italy (193) respectively. This period has been followed by the substantial stand–by around an average of more or less 250 for the first half of the '80s. Since then R&D has shown a very substantial increase, reaching an average of 892 in 1992, with Germany and Great Britain respectively as top (1294) and worst performer (639). Along the period considered (1973–1992), the four countries have experienced an average compounded rate of growth equal to 11.6%. Germany has the highest growth rate (13.7%), followed by Italy (11.3%), France (10.8%), and Great Britain (9.7%).

Figure 3: Quota of R&D in motor vehicles on total manufacturing production

Figure 3 shows the quota of motor vehicles R&D expenditure on total manufacturing production from 1973 to 1991, while in Figure 4 the R&D intensity of the motor vehicles for the four countries considered is shown.

The two figures show some interesting elements relative to the relationships among the two building blocks of the automobile TS, which refer to the innovative and the production activities respectively. Indeed, on the one hand, Figure 3 confirms what has been previously said with regard to the marked differences in the R&D expenditure patterns along time, while adding some more information. The first thing to emerge is a quite straightforward confirmation of the diverging patterns in innovative activity as far as the input indicator is concerned. Germany is well above the rest of the sample, Italy and Great Britain are characterised by very similar

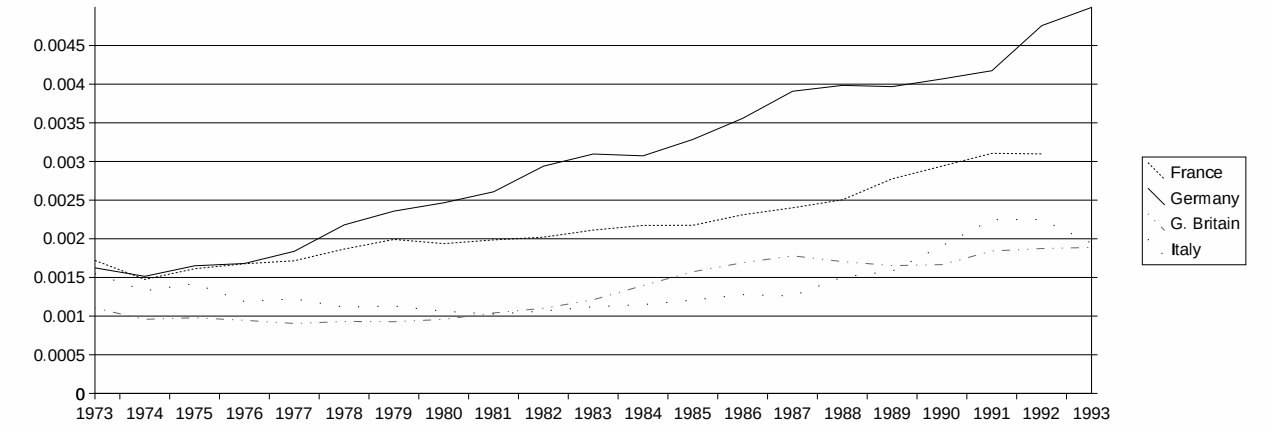

Figure 4: R&D intensity in the motor vehicles

patterns, and France is in an intermediate position. However, the trend in manufacturing weighted R&D expenditure results to be less cyclical than that resulting from the consideration of R&D expenditure alone, especially for Germany and France. This seems to point to the fact that R&D expenditure appears to be linked to the necessities of the economy and thus its cyclical variations are in some cases the result of cyclical variations in the economic performance.

A glance at Figure 4 further confirms this evidence, in particular for Germany and France, with almost coincident and relatively steady patterns. The case of Great Britain and Italy is quite different. Firstly, their R&D intenssity is lower along the whole period. Secondly, they show more pronounced cyclical variations, hinting how the attention devoted to the automobile sector, with respect to the others, is less structural than in Germany and France. More in particular, Great Britain shows a worsening of its innovative intensity starting from the mid '80s. Italy has a very pronounced peak, possibly due to cycles on the production side. On the contrary, in the final years of the period, the relative incidence of R&D increases to reach and overcome that of France. The latter is the most relevant temporal change we observe, hinting at an interesting case of eventual catching up, at least in terms of R&D intensity, of the Italian automobile TS with respect to the others.

We now turn to the analysis of the output of the innovative activity, which is normally assumed to be reflected in the patenting activity. In order to depurate the analysis from

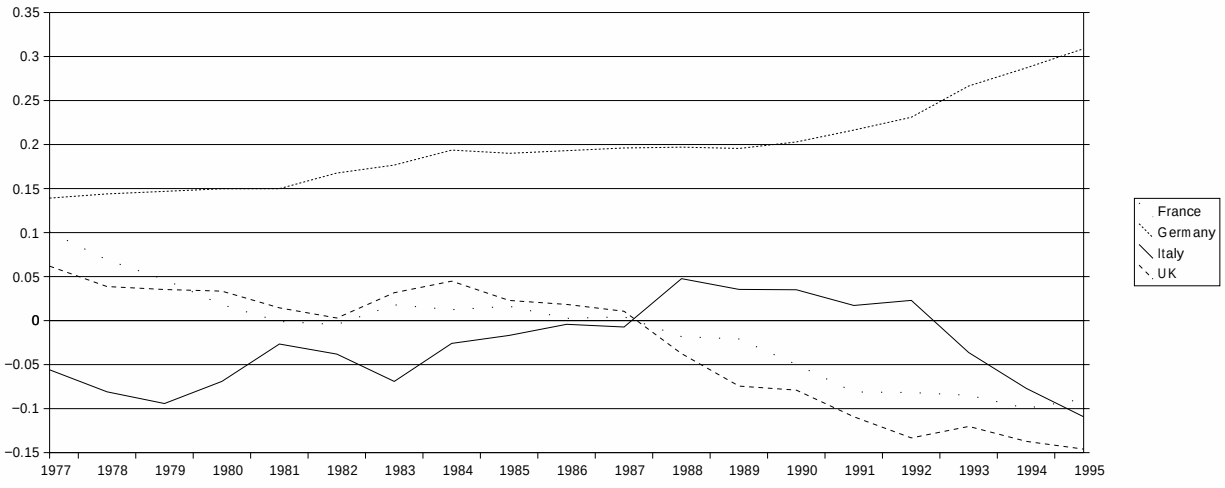

Figure 5: Motor vehicles NRTA, five years moving average

inevitable institutional differences between the patent offices of the various countries, first of all, we will refer to the number of patents granted in the US Patents and Trademark Office during the period 1977-1995 (USPTO, OEIP/TAF Database, 1996). Furthermore, to get rid of scale effects, we will compute a Revealed Technological Advantages index (RTA), which is nothing but a standard specialisation Balassa index based on patent counts. For the generic sector k of country i, the indicator is thus defined as follows:

$$RTA_i^k = \frac{Pat_i^k / \sum_i Pat_i^k}{\sum_k Pat_i^k / \sum_k \sum_i Pat_i^k}$$

where Pat_i^k denotes the patents granted to country i in sector k. This indicator has the usual meaning. In fact, it indicates a certain degree of technological specialisation in sector k of country i if it is greater than one, and technological despecialisation with respect to total manufacturing if it is less than one.

Having no upper limit, this indicator can be normalised in a simple way:

$$NRTA_i^k = \frac{RTA_i^k - 1}{RTA_i^k + 1}.$$

Accordingly, country i turns out to be specialised in sector k if $-1 < NRTA_i^k < 0$, while it is despecialised if $0 < NRTA_i^k < 1$.

The analysis of Figure 5 shows quite clear patterns. Indeed, a rather evident diverging trend in patenting emerges, suggesting an increasing level of polarisation in the innovative results of the different TS. Germany is in fact the only country with positive and increasing values of the NRTA for the whole period examined. On the opposite, the rest of the countries experience a decline in their relative technological advantages, though with different intensity. France has the steepest declining trend. Starting from positive values in 1977 (NRTA = 0.10), only slightly lower than that of Germany (NRTA = 0.14), it ends up with a very wide gap. Great Britain shows more or less the same pattern as France, but with a more pronounced decrease starting from the mid '80s, and it ends up with the lowest NRTA value (-0.15) at the end of the period. Italy has once more the most varied trajectory. In fact, it shows a cyclical upward trend that lasts until the end of the '80s, peaking in 1988 to the positive value of 0.05. Then it starts a mild decline until 1992, with positive values, followed by a steep decline that reaches the absolute minimum at the end of the period in 1995 (RTA = -0.11).

In conclusion, three are the main evidences emerging from this analysis. First, the steady increase of the motor vehicles technological comparative advantage of Germany, which therefore seems to have been the explicit target of its technological activity. Second, the irregular but apparent increase in the automobile despecialisation of France and Great Britain, which suggests a possible shift in their sectoral technological activity. Finally, the performance of Great Britain and Italy, which appears to be more contrasted and in need of a more complete kind of analysis in order to exhaust the whole spectrum of possible causes.

4.2 Innovative pervasivity and dependency

As in the case of the industry side, also for the innovative side a deeper analysis is carried out with respect to relational kind of aspects.

A first preliminary indicator of the techno–economic interrelationships within the automobile TS can be considered that of the innovative pervasivity or dependency of the correspondent economic sector. Indeed, similarly to the backward and forward linkages indicators, the pervasivity/dependency ones identify the role of a certain sector within a certain web of interactions, but this time in innovative terms, by looking at intersectoral innovation rather than production flows. Once again, the reference can be to either direct or total innovation flows, and the latter can in turn be measured in different ways (Montresor, 1998). However, as we have argued elsewhere (Leoncini *et al.*, 1996), the analysis of innovation flows embodied into total production flows, in turn activated by the final demand, reveals the most consistent with the notion of TS we consider. Accordingly, the same indicators will be built up on the basis of a matrix defined as $\mathbf{F} = \hat{\mathbf{r}}\mathbf{R}$, where $\hat{\mathbf{r}}$ is the diagonal vector of the selected innovative proxy (in this case R&D

expenditure), and $\mathbf{R}$ is defined as $\mathbf{R} = (\hat{\mathbf{x}})^{-1}\mathbf{B}\hat{\mathbf{d}}$, where $\hat{\mathbf{d}}$ is the diagonal vector of sectoral final demand.

As each element of $\mathbf{F}$, f_{ij}, measures the innovation produced by sector i and embodied in the final production of sector j, a first absolute index of pervasivity/dependency (APD) can be defined for sector k as:

$$APD_k = \frac{D_k - I_k}{A_k - I_k} = \frac{\sum_j f_{kj} - f_{kk}}{\sum_i f_{ik} - f_{kk}}$$

where D_k are the innovative diffusions of sector k (i.e. the row total of the innovation flows matrix, $\mathbf{F}$, for the same sector), A_k the innovative acquisitions (i.e. the column total of $\mathbf{F}$ for the same sector), while I_k stands for the intrasectoral diffusions of the sector itself, as from the correspondent cell on the principal diagonal. Since we are interested only in intersectoral relationships, such diffusions will be left out, so that the numerator and the denominator denote, respectively, net diffusions and net acquisitions.

The meaning of the indicator is quite straightforward. If $ADP_k > 1$, sector k is said to be pervasive, that is, its intersectoral innovative acquisitions are less than its diffusions. The reverse holds if $0 < ADP_k < 1$, as sector k, in this case, depends on the rest of the economic sectors for its innovative inputs more than the others depend on it.

Since the previous index has no upper ceiling, it can be normalised as follows:

$$NPD_k = \frac{APD_k - 1}{APD_k + 1}.$$

In this way, k will turn out to be dependent if $-1 < NPD_k < 0$, while it will be pervasive if $0 < NPD_k < 1$.

The two indexes are showed in Table 4 for comparable years with the previous ly calculated indicators.[8]

Similarly to the industrial analysis, on which, to a certain extent, the innovative one is based,[9] the data show that, as expected, the automobile sector is quite dependent for its technological acquisitions on the rest of the economic sectors. In absolute terms, its innovative diffusions do not generally reach 10% of the corresponding acquisitions. This is particularly true for France, where they are stable around 2%, while in Great Britain the innovative diffusions are as much as 10% of the acquisitions.

[8]To be sure, as the data on sectoral R&D (DSTI (STAN, Anberd), 1994) are not available before 1973 on a comparable basis, the earlier years of the two indicators series do not coincide. The same holds for the relative sectoral disaggregation. By matching I–O tables with R&D data we have in fact a less disaggregated classification of 19 sectors (see Appendix A.2).

[9]Let us remember that the innovative flows utilised to produce the ADP indicators are embodied in intersectoral production flows.

Table 4: Motor vehicles innovative pervasivity and dependency

France	1977	1980	1985	1990
Absolute	0.026	0.022	0.024	0.026
Normalised	-0.950	-0.956	-0.953	-0.949
Germany	1978	1986	1988	1990
Absolute	0.070	0.074	0.072	0.078
Normalised	-0.870	-0.862	-0.865	-0.855
G. Britain		1979	1984	1990
Absolute		0.049	0.095	0.157
Normalised		-0.906	-0.827	-0.728
Italy			1985	
Absolute			0.052	
Normalised			-0.901	

Different patterns can however be identified by looking at the normalised values of the indicator. France has the lowest and most stable values of the four countries, as the relevant indicator decreases only slightly over time. Accordingly, the French motor vehicles sector reveals the most structurally dependent of the four. The well known strength of this sector therefore seems to rely on a substantial contribution of the other sectors, to whose identification we turn in the next section.

For Germany also the normalised indicator shows a remarkable degree of stability over time, but for higher values than those for France. Indeed, in relative terms the German motor vehicles sector is the most pervasive (least dependent) of the four, contributing to explain the greater connectivity of the correspondent national TS (Leoncini and Montresor, 1999b).

Italy has only one available year[10] which is quite low (-0.901). A very dependent nature seems therefore to confirm the well–known backward innovative linkages which establish between the Italian monopolist of the sector and a dense network of specialised suppliers.

Finally, a very interesting pattern emerges for Great Britain, showing an appreaciable increase over time of the normalised indicator. The sustained process of internationalisation, which has characterised the sector along the '80s, seems therefore to have also made it more internally pervasive.

Although quite instructive, the pervasivity/depencendy indicator is a synthetic one, as it identifies the role of a certain sector in the innovation relationships, rather than the relationships

[10]The *caveat* for it are the same raised in the preceding paragraph.

themselves. Hence, more details about the latter can be obtained by mapping the relevant innovation flows, a task we will accomplish in the next section.

4.3 Network analysis

The application of quite standard network analysis techniques to the intersectoral innovation flows matrices we have referred above (that is the **F** matrices) is quite helpful in analysing the characteristic structure of a certain national TS (Leoncini and Montresor, 1999a). The same holds true also for the sectoral TS in which the former can be disaggregated. Indeed, once the intersectoral innovation flows have been properly normalised (i.e. transformed into relative intersectoral innovative acquisitions[11]), and, in turn, dichotomised with respect to a certain cut-off value (t^*)[12], the innovative centrality of a certain sector, k, can be worked out. Hence, its innovative diffusions and acquisitions can be mapped with respect to the other sectors.

As far as the centrality is concerned[13], it measures how important a certain sector k is by simply counting the number of sectors it 'innovates' (outdegree centrality, ODC_k) or by which it is innovated (indegree centrality, IDC_k):

$$ODC_k = \sum_j f^{*d}_{kj}; IDC_k = \sum_i f^{*d}_{ik}$$

Let us observe that, at this stage, it is the number of innovative edges and not their specific sectoral identity, which matters, an aspect that we will instead consider in what follows.

Table 5 shows the values of these two indicators for the automobile sector in the four countries considered and for the available periods (see the previous section for information on the data source). In order to make our analysis less dependent on the arbitrariness of the threshold selection, three cut–off values have been chosen, referring to, respectively, nearly all (greater than 0.1% of the total, i.e. $t^* = 0.001$), 'medium' (greater than 0.3%, i.e. $t^* = 0.003$), and 'large' (greater than 0.5%, i.e. $t^* = 0.005$) innovative flows.

[11] This simply amounts to considering a matrix $\mathbf{F}^*$, defined as:

$$\mathbf{F}^* = \mathbf{F}(\hat{\mathbf{f}})^{-1}$$

where $\hat{\mathbf{f}}$ is the diagonal vector of total sectoral innovative acquisitions, that is the sum by column of **F**.

[12] As it is well known, this means transforming the elements of $\mathbf{F}^*$ into 0s and 1s, according to a 'greater than' test such as the following:

$$f^{*d}_{ij} = 1 \text{ if } f^*_{ij} \geq t^*; f^{*d}_{ij} = 0 \text{ else}$$

where f^*_{ij} and f^{*d}_{ij} are the generic elements of $\mathbf{F}^*$ and of $\mathbf{F}^*$ dichotomised ($\mathbf{F}^{*\mathbf{d}}$) respectively.

[13] Out of the various formulations, in the following we will refer to the most simple, that is to the so called 'Freeman degree centrality' (Scott, 1991).

Table 5: Motor vehicles Freeman's degree centrality

Cut–off values	**0.005**		**0.003**		**0.001**	
	In	Out	In	Out	In	Out
France						
1977	7	1	10	7	11	10
1980	6	1	10	5	11	9
1985	7	1	11	6	12	9
1990	7	1	9	7	11	10
Germany						
1978	6	9	8	13	9	14
1986	7	10	8	13	9	16
1988	7	10	8	14	9	16
1990	6	10	8	14	9	16
Great Britain						
1979	7	6	10	8	14	12
1984	7	6	8	8	12	12
1990	8	10	9	13	13	17
Italy						
1985	5	2	6	2	9	10

A first important observation is strictly related to those of the previous section. In general, the indegree centrality values are greater than the outdegree ones, thus confirming the dependent nature of the sector. However, this does not hold for Germany, where, for all the flows we have retained, it is pervasive. To be sure, this kind of switches, with respect to the aggregate analysis performed in the previous section, can also be found in other countries, but they are more limited. In the case of Great Britain, for example, the sector turns from dependent into pervasive, moving from the middle '80s to the early '90s, in particular with respect to medium/large flows. This occurs in the case of Italy as well, but only when small flows are retained. As we have previously said, the former result can be linked, to a certain extent, to the internationalisation of the British automobile sector. In the case of Italy, instead, the same switch seems to show how the consideration of those innovative interrelationships which possibly involve also small suppliers, of both components and final products, is able to change the nature of the same sector quite substantially.

A second important observation concerns the different importance (i.e. centrality) that the automobile sector reveals in the four countries for flows of different magnitude.

As for the outdegree values, the German automobile sector is the most central with respect to all the cut–off values and, what is more, with relatively less 'drops' in cutting out small and medium innovative acquisitions, that is, in moving from 0.001 to 0.005. Always from an outward perspective, the British automobile sector is the second most central for all the cut–off values, but, this time, the relative indicator decreases substantially in moving from 0.001 to 0.003, and less from 0.003 to 0.005: small size diffusions therefore seem to be particular relevant also in Great Britain. As far as France and Italy are concerned, the innovative diffusions are relatively less consistent. Furthermore, the changes we observe in increasing the magnitude of the relevant threshold are much more consistent. In particular, in France the innovative diffusions of the motor vehicles which overcome the largest reference flow (i.e. 0.005) reach one sector only, while, in Italy, it suffices to leave out flows of medium dimension to confine its pervasivity to two sectors only.

Substantially different results emerge from the analysis of the indegree centrality. At first, let us observe that the differences between the four countries in the considered sector are less evident than for the outdegree values, with the partial exception of the smallest of the cut–off values (0.001). The 'homogenising' effect of their input–output structures (caught by the columns) seems therefore to weight more than the 'differentiating' effect entailed by their R&D system (caught by the rows). Also the differences we observe in moving between the cut–off values appear generally less substantial than for the outdegree values. Acquisitions seem therefore more homogeneous than diffusions for the present cut–off values, as their critical thresholds are possibly higher. Finally, also the rank of the countries is substantially different. Apart from 0.003, with respect to which they are slightly dominated by France, the acquisitions of the British automobile sector count more than in the other countries. This is particularly true when nearly all the flows are considered (that is, for 0.001), while in retaining medium and large flows the acquisitions reduce substantially. What we have previously observed in aggregate terms, therefore, finds a confirmation only for a limited subset of innovation flows. This is even more true for Italy, as the dependent nature of its automobile sector appears evident only when flows of a certain magnitude are left out. The indegree centrality of the sector in France and Germany is instead more stable across the cut–off values, and intermediate with respect to that of Great Britain and Italy. As in aggregate terms, the French acquisitions are more consistent than the German ones, although the consideration of large flows only entails a certain homogenisation.

A last remark is due for the temporal changes we observe in the centrality indicators. To be sure, in general, they are not so relevant, so that the automobile sector appears as much central at the beginning as at the end of the considered period, in all countries and for all the cut–off values.

In general terms, let us observe that, as we expected, the outdegree centrality is slightly more variable than the indegree. Indeed, the incidence of R&D expenditure varies more than

the input–output structures along time. However, the temporal changes are relatively more consistent when both small and large flows are considered, while the reference to large flows only entails a greater degree of stability.

More specifically, as we have already observed at aggregate level, the most consistent variations concern Great Britain, where the outdegree centrality of the automobile sector increases substantially for all the cut–off values, in particular from 1984 to 1990. Furthermore, a part from the large flows, also its indegree centrality progressively decreases along time. As for the rest, if we except the outdegree 'jumps' revealed by Germany, the centrality of the automobile sector remains quite stable.

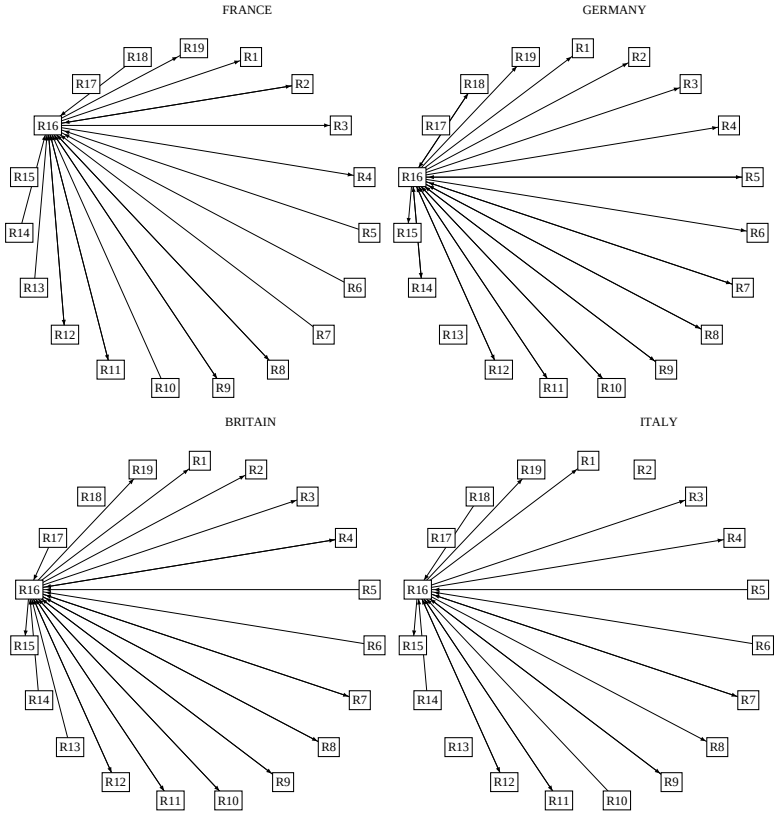

Figure 6: Oriented graphs (1985, cut–off = 0.001)

If the previous analysis just refers to the number of innovative diffusions and acquisitions of the automobile sector, more qualitative considerations about their destination and origin can be obtained by applying to $\mathbf{F}^{*\mathbf{d}}$ another typical network analysis technique, that of the *oriented graphs*. As it is well known, these are the simple graphical dual of the same matri-

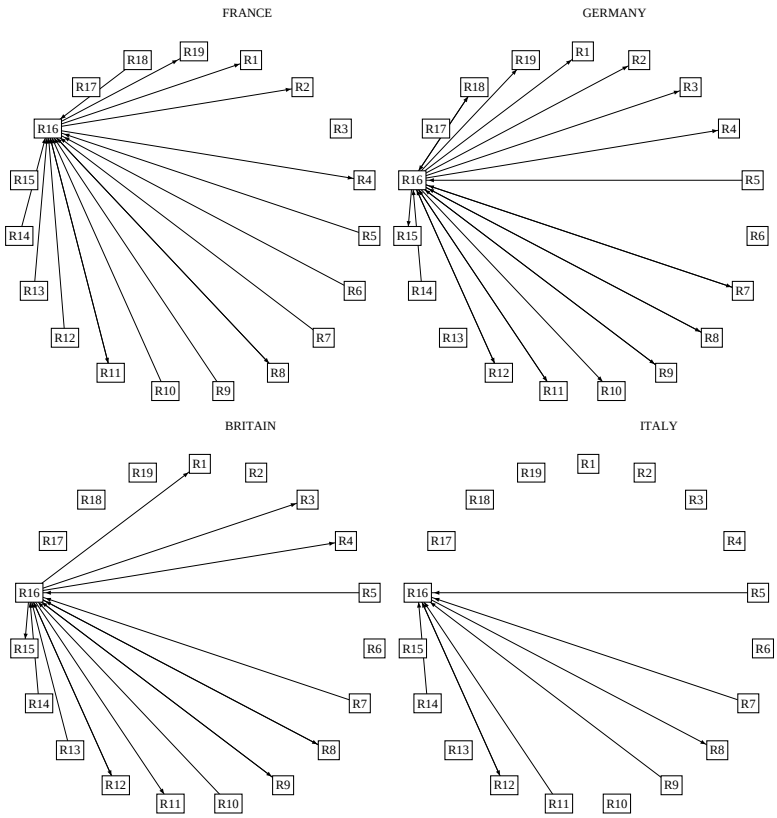

Figure 7: Oriented graphs (1985, cut–off = 0.003)

ces. Nevertheless, as they show the relevant sectors and innovation flows as *nodes* and *edges*, respectively, these graphs allow us to better visualise the map of the interrelationships which refer to a certain sector.

Figures 6-8 report, for the four countries of our sample, the automobile–based edges of such oriented graphs, for the three cut–off values that have been selected, and with respect to the middle '80s only. In other words, they visualise the linkages of the 'automobile network', a network that can be obtained by leaving out all those edges which do not originate from, or converge to the motor vehicles sector. As far as the temporal choice is concerned, as we have seen in the previous centrality analysis, the most apparent changes occur in considering innovative flows of different magnitude, rather than the same kind of flows with respect to different periods. Accordingly, the evaluation has been limited to the period with the most numerous observations.

When nearly all the innovative flows are considered ($t^* = 0.001$), the four graphs are quite

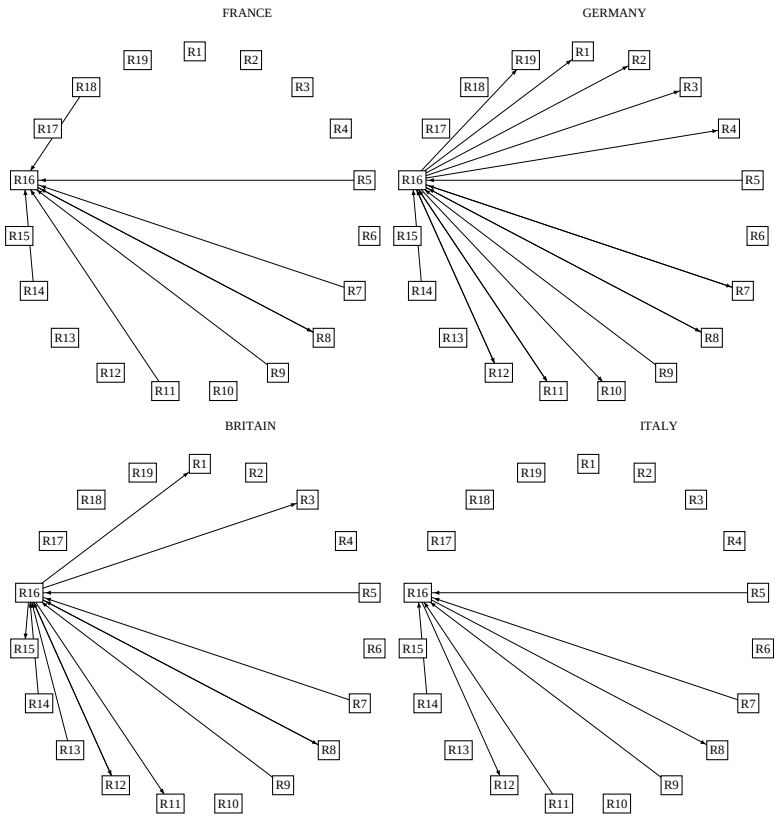

Figure 8: Oriented graphs (1985, cut–off = 0.005)

similar (Figure 6). Indeed, the density of the automobile network — defined as the ratio between the number of 'actua'l and 'potential' automobile based innovative flows — is in the case of France and Italy only slightly lower than in Great Britain and Germany: that is, 0.061 and 0.055, versus 0.070 and 0.073.[14]

As far as the flows direction is concerned, as expected, the automobile industry (Sector 16)[15] reveals in general purely 'diffusive' only with respect to the most traditional sectors of

[14]The density of a certain sectoral network, i, with respect to a certain cut–off value, k, ($DEN_{i,k}$), is defined as:

$$DEN_{i,k} = \frac{n_{i,k}}{n(n-1)}$$

where $n_{i,k}$ is the number of edges greater than k, which come either from or to sector i, while $n(n-1)$ are the total potential intersectoral linkages, with n equal to the number of the sectors (in this case, $342 = 19 * 18$).

[15]For the sectoral disaggregation utilised here, see Appendix A2.

the disaggregation (Sectors 1-4), and to the residual one (Sector 19). The only exception is that of the textiles (Sector 2), from which it receives innovative flows above the threshold in France, while it does not receive flows at all from it in Italy. As much expected is the fact that the automobile sector is purely 'acquisitive' with respect to the chemical (Sector 5) and the energetic products (Sector 6) sectors. However, the underlying techno–economic relationships become bijective with respect to the chemicals in Germany, thus providing us with a further confirmation of the more interconnected nature of its national innovation system.

A similar 'acquisitive' argument, this time for the external parts and the engines, also holds with respect to non-ferrous metals (Sector 10) and electrical equipment (Sector 14), which benefit from substantial motor vehicles innovations only in Germany and, for the former, also in Great Britain.

As far as the remaining sectors are concerned, the automobile industry establishes bijective innovative relationships with nearly all those sectors which supply to it physical kind of artefacts (Sectors 7, 8, 9, 11 and 12), with the exception of rubber and plastic (Sector 7), only diffusive in France, and of non metallic mineral products (Sector 8), only acquisitive in Italy. The relationships with the suppliers of more 'sophisticated' components, typically in the office & computing machinery sector (Sector 13), are instead purely acquisitive in France and Great Britain, or even below the relative threshold in Germany and Italy.

Finally, the innovative relationships turn out in general quite rare with the other transport equipment sectors (Sectors 15 and 17), and with the professional goods one (Sector 18). This is particularly true for the aircraft sector (Sector 17), which is in general isolated from the automobile one, with the only exception of Great Britain, while the professional goods sector (Sector 18) develops biunivocal relationships with the motor vehicles only in Germany.

The comparison between the graphs of the automobile network shows greater elements of differentiation when only medium and large innovative flows are retained ($t^* = 0.003$). In fact, Great Britain (with a density value of 0.046) and, above all, Italy (with $DEN_{0.03} = 0.023$), appear now less articulated than France ($DEN_{0.03} = 0.049$) and Germany ($DEN_{0.03} = 0.064$), showing the most connected network (Figure 7).

As far as the map of the linkages is concerned, let us observe that those sectors which make the motor vehicles less central in terms of outdegree in Great Britain and, in particular, in Italy, are some of the most traditional, the residual (Sector 19) and the professional goods sector (Sector 18). Indeed, these sectors remain the 'target' of substantial automobile innovative flows only in Germany and, to a lesser extent, in France. Secondly, although apparently similar in their higher density, the automobile networks of France and Germany are now more diverse. In particular, much of the biunivocal relationships established in Germany with the suppliers of physical artefacts (Sectors 7–12) turn in France into purely acquisitive, with the only exception of the non-metallic mineral products (Sector 8). When only flows of an appreciable magnitude are considered, the energetic products sector (Sector 6) gets totally disconnected from the

automobile one, while the same occurs also for the non-ferrous metals (Sector 10), but in Italy only. That the relationships between these two sectors are in the Italian system of innovation substantially affected by small innovation and production flows therefore emerges once more here and more precisely.

When only large innovation flows are considered ($t^* = 0.005$), the density gap between the German and the other automobile TS becomes more apparent (Figure 8). The percentage of actual innovative linkages is, in the first case, of nearly 5% of the total, while it is around 4% in Great Britain ($DEN_{0.05} = 0.038$), and 2% in France and Italy ($DEN_{0.05} = 0.023$ and $DEN_{0.05} = 0.020$, respectively).

More precisely, the only innovative flows that survive the dichotomisation in France and in Italy refer to some of the sectors of the central part of the disaggregation (Sectors 7, 9, 11), to which it adds the professional good sector (Sector 18) in France. Furthermore, a part from the non-metallic mineral products (Sector 8), these relationships are all univocal and identify innovative transfers towards the motor vehicles sector. The same kind of univocal relationships can be also identified in Great Britain, where 'large' diffusions can however still be identified from the automobile sector to food & beverages (Sector 1) and to textiles (Sector 2).

Confirming what can be observed by looking at all the innovative interrelationships (Leoncini and Montresor, 1999b), the German automobile network is by far the most dense. On the one hand, the only sectors which fall out of the network are the energetic products (Sector 6) and the aircraft sector (Sectors 17) as in the other countries, the professional goods sector (Sector 18) as in Great Britain and Italy, and the office & computing industry as in Italy. On the other hand, much of the suppliers of the relevant physical components receive substantial innovative flows from the automobile sector.

5 The international side

The relationships we have considered in the previous paragraphs are exclusively internal. In other words, we have focus our attention on those production and innovation interactions that the automobile TS establishes within the country where the relative companies reside. However, as we have said at the beginning, the sectoral TS extends also outside the country of their home–base, and through different material and immaterial exchanges.

Among the other, trade flows and foreign direct investments represent two channels whose analysis can be useful in disentangling the actual degree of internationalisation (trade) and transnationalisation (FDI) of the automobile TS. To these flows we now turn our attention.

Table 6: Motor vehicles bilateral revealed comparative advantages

		EU	USA	Japan	Brazil	Check Rep.	Sing.	China	OECD	Non OECD
1975	France	1.64	0.31	0.32	0.34	3.03	1.20	2.27	1.08	1.21
	Germany	1.33	1.44	3.35	1.14	0.78	2.19	0.14	1.10	1.49
	G. Britain	1.11	0.50	1.04	0.91	1.20	2.50	0.42	0.81	1.21
	Italy	1.06	0.76	0.95	0.67	2.02	1.64	2.54	0.82	0.95
1980	France	1.50	0.45	0.47	0.38	2.11	0.46	1.58	1.10	1.18
	Germany	1.48	1.49	5.82	1.23	1.10	1.94	1.30	1.30	1.41
	G. Britain	0.88	0.38	1.67	2.30	1.53	1.39	0.20	0.66	1.09
	Italy	0.84	0.47	1.12	2.55	2.00	1.16	0.25	0.67	0.78
1985	France	1.30	0.31	0.30	1.36	0.75	0.48	0.67	0.74	1.23
	Germany	1.55	1.31	6.52	1.38	1.15	2.12	0.56	1.15	1.46
	G. Britain	0.64	0.32	0.81	1.37	0.82	1.43	0.59	0.43	0.81
	Italy	0.70	0.15	0.66	1.48	1.65	2.90	0.48	0.40	0.64
1990	France	1.25	0.26	0.71	2.39	2.20	0.59	1.22	0.94	1.20
	Germany	1.42	1.09	4.38	1.42	1.32	2.56	2.61	1.26	1.35
	G. Britain	0.85	0.36	1.21	2.14	0.52	1.32	0.74	0.66	0.69
	Italy	0.76	0.24	0.52	1.37	0.80	2.07	0.19	0.58	0.60
1993	France	1.23	0.23	0.36	0.56	1.06	0.44	1.72	0.88	0.91
	Germany	1.38	0.94	4.26	1.21	1.08	3.37	1.97	1.17	1.40
	G. Britain	0.92	0.28	1.17	0.95	0.48	1.64	0.91	0.66	0.56
	Italy	0.64	0.16	0.59	2.04	0.96	1.47	0.28	0.47	0.59

5.1 Bilateral revealed comparative advantages

As it is well known, one of the most common index for analysing the sectoral structure of the international relationships of one country is the Balassa index of revealed comparative advantages. However, we are also interested in mapping the degree of specialisation/despecialisation with respect to specific countries/regions. Such a combined analysis of sectoral specialisation/despecialisation and bilateral relations can be carried out with respect to trade flows, and reveals quite useful in determining the actual degree of international extension of the correspondent TS. In order to perform this analysis, in the following we work out for the automobile

sector a Bilateral Revealed Comparative Advantages indicator (BRCA), defined as follows:

$$BRCA^{j}_{i,k} = \frac{Exp^{j}_{i,k} / \sum_i Exp^{j}_{i,k}}{\sum_k Exp^{j}_{i,k} / \sum_k \sum_i Exp^{j}_{i,k}}$$

where $Exp^{j}_{i,k}$ denotes the export made by country i in sector k to country j. In other words, the BRCA is nothing but the ratio between the sectoral and the total export shares of a certain origin country i to a destination country j.

As for the standard RCA, the meaning of this indicator depends on its values being greater or lower than one. In the former case, it shows a revealed bilateral comparative advantage, that is, the exports of the automobile sector perform better than those of the rest of the industrial sectors in a certain country. Hence, we have a relative specialisation in this sector, but with respect to a specific geographical area. The opposite holds for values less than one, which indicate a relative despecialisation in automobile manufacturing with respect to a certain area.

Therefore, the reference to bilateral, rather than to standard RCA allows us to map geographically the relative strength of a certain country in the automobile sector. We are thus able to compare the different spatial patterns of internationalisation that the relative TS has undergone, at least by allocating the national production abroad.

As far as the calculations are concerned, the reference years have been chosen in order to work out the BRCA indicator for the same periods of the previous indicators (Table 6).[16] As for the destination countries, they have been chosen in order to give an account of the automobile international specialisation in the main world markets, both established, such as the EU, USA and Japan, and emerging, such as South Eastern and South Western Asia (Singapore and China) and Latin America (Brazil), although we are aware that this choice may lead to some distorted results.

The results we have obtained with respect to the European market confirm our expectations to a certain extent. France and Germany are the only countries, out of the four, with a persistent specialisation in this area. Furthermore, the recent expansion of the mergers and acquisition activities of the German car producers seems to be confirmed by the shift we observed in the magnitude of the BRCA indexes from France, which has the highest values until the early '80s, to Germany, which, although following a decreasing pattern, overcome France from then on. The comparative advantages initially revealed by Great Britain and Italy turn into a progressive disadvantage in the early '80s, partially recovered by Great Britain only, in the most recent period. Also in this case, the pattern in the BRCA of the two countries is decreasing, insofar suggesting the penetration of other car producers in Europe (notably from the Far East).

[16]The data on trade flows are taken from the OECD STAN database on Bilateral Trade (DSTI (STAN, Bilateral Trade Database), 1997).

Moreover, it also emerges that Great Britain and Italy might have shifted their specialisation area, rather than competing with France and Germany in the same market. A suggestive example is given by the case of the Brazilian market, in which, since the early '80s, both Italy and Great Britain acquire specialisation which are greater than, or at least comparable with, those of France and Germany. A similar argument seems to hold for the case of Singapore, where Italy and Great Britain are however still dominated by Germany.

Germany appears the only competitive car producer of the four in the USA, although with a decreasing trend, and, more evidently, in Japan, where Great Britain only reveals a certain degree of specialisation. Furthermore, in the most recent period, Germany also overcomes the previously unique and consistent specialisation of France in the Chinese market.

A last specific remark concerns the Eastern market, here represented by the Check Republic. Here as well, a certain change emerges which confirms the increasing internationalisation of the German car producers. Until the early '80s, France and Italy revealed the most competitive producers in that area. However, entering the globalization phase, Italy looses its comparative advantages, apparently at the expenses of Germany, which joins France as the only specialised country in the Check Republic.

5.2 Foreign Direct Investments

As it is generally argued, one characteristic of the globalization process is that the volume of foreign direct investments (FDI) has been increasing more than exports as a means of international integration (OECD, 1992, Ch. 10). Indeed, by establishing production and innovation units abroad, firms have turned from purely *international* to *transnational*, if not even *global*.

This is true, in particular, for the motor vehicles sector, for which the geographical dispersion of the subsidiaries of a certain parent company around the world is becoming so widespread that, in some cases, the actual nationality of an automobile transnational corporations (TNC) could not be determined on the basis of a purely territorial criterion. A certain confirmation of this fact can be obtained by looking at the largest transnational corporations (abroad) and foreign affiliates (in the host economy) of the four countries analysed, in terms of sales (Table 7).

First of all, firms operating in the motor vehicles sector are the biggest transnational corporations in three out of the four countries examined, where these firms rank in the first three positions apart from one case (Germany). As far as the foreign penetration in these countries is concerned, again, the dimension of the automobile foreign affiliates is quite big, with the only exception of Italy. However, it is Italian the only non–USA foreign affiliate (in France).

By combining the two previous bits of analysis, a certain level of differentiation seems to emerge among two groups of countries: France and Germany, on the one hand, and Great Britain and Italy, on the other. Indeed, the former group seems to be characterised by a certain

Table 7: Ranking of motor vehicles companies among the 10 largest TNC and among the largest foreign affiliates by sales (1988)

Largest transnational corporations abroad			
	Company	(Rank)	Sales (mil US$)
France	Regie Nationale des Usines Renault S.A.	(1)	10,313.7
	Peugeot S.A.	(2)	23,242.3
Germany	Daimler Benz AG	(1)	41,848.2
	Volkswagen AG	(3)	33,720.5
	BMW AG	(10)	13,931.5
G. Britain	...		...
Italy	Fiat S.p.a.	(1)	37,812.1

Largest foreign affiliates in host economy				
	Company	(Rank)	Home economy	Sales (mil US$)
France	Fiat France	(4)	Italy	4,237.6
Germany	Ford-Werke AG	(1)	USA	10,959.3
	Adam Opel AG	(2)	USA	9,942.9
G. Britain	Ford Motor Co. Ltd	(1)	USA	10,559.1
	Vauxhall Motors Ltd.	(7)	USA	3,477.6
Italy	...		...	...

Source: UNCTAD (1993).

balance between the presence abroad and that at home of automobile TNC. Great Britain and Italy, instead, have very unbalanced, although opposite, characterisations (inward in one case, outward in the other). This seems to be a clear consequence, for Italy, of the monopolistic position of its only national producer, which makes the penetration of foreign producers more difficult, and for Great Britain, on the contrary, the result of the progressive lost of a 'true' national champion.

Similarly to the case of exports, also with respect to FDI, it is interesting to establish if the motor vehicles sector is one in which a country reveals a comparative advantage or disadvantage. Indeed, the motor vehicles sector is not necessarily the largest recipient one of the four countries. To be sure, this is only true for Italy and Germany, but only as far as outward FDI are concerned (UNCTAD, 1993).

As for exports and patents, also with respect to outward FDI, a revealed comparative advantage in sector j for the transnational activities of country i (RTNA) can be calculated, in

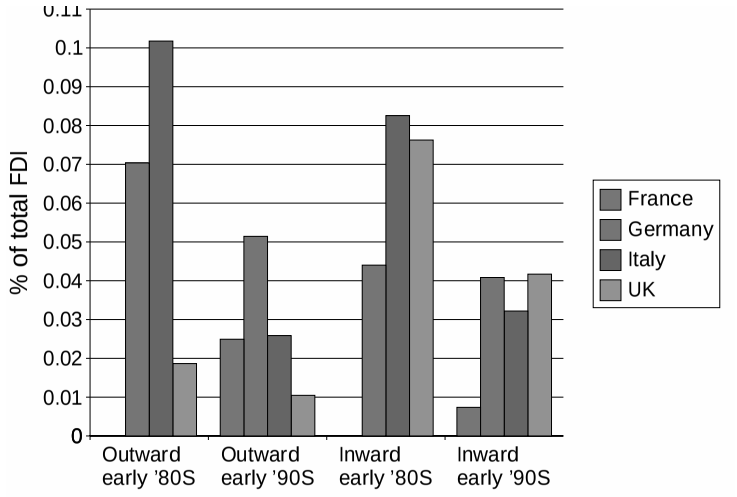

Figure 9: Stock of motor vehicles FDI on total FDI stock

order to know if the transnational activities of one country are characterised by a specialisation in the automobile sector or not:

$$RTNA_{i,j} = \frac{FDI_{i,j}/\sum_i FDI_{i,j}}{\sum_j FDI_{i,j}/\sum_i \sum_j FDI_{i,j}}.$$

For reasons that will appear clear in a while, it is convenient to rearrange the previous formula as the ratio between the sectoral FDI share of country i and that of the 'World' of reference:

$$RTNA_{i,j} = \frac{FDI_{i,j}/\sum_j FDI_{i,j}}{\sum_i FDI_{i,j}/\sum_i \sum_j FDI_{i,j}}.$$

The numerator of the previous equation is a first indicator of the 'absolute' importance of sector j for the transnational activities of country i. The data to build up such an indicator with respect to the motor vehicles sector are available for all of our countries for the early '80s and the early '90s, although the reference years are not the same (Figure 9).[17]

As far as the outward stock is concerned, the automobile TS appears to be very important in Italy in the early '80s (about 10%), and in Germany in the early '90s (about 8%). On the contrary, France and Great Britain lag quite behind. To be sure, the shift we observe in the

[17]More precisely, the data for France refer to 1982 and 1989, those for Germany and Italy to 1980 and 1990, and those for Great Britain to 1981 and 1987 (UNCTAD, 1993).

leadership along the decade is the result of a more general trend. Indeed, the relative weight of the transnational activities of the automobile TS decreases in general from the early '80s, possibly because of the extension of the transnational activities of the other manufacturing sectors.

Coming now to the inward FDI stocks, their incidence on manufacturing is the highest in Italy and Great Britain (around 8%) in the early '80s, with a consistent gap with respect to Germany (about 4%). Following the decrease undergone by the sector also in inward terms, the rank appears quite different in the early '90s. In fact, with the exception of France (where it has a very low weight, less than 1%), Italy and Great Britain are joined by Germany around a share of 3–4% of all the manufacturing inward stocks.

As a result of these temporal changes, Italy, which experiences the biggest drop in both types of FDI, shows a structural kind of change, turning from a net exporter to a net recipient. The decrease is less consistent for the inward FDI of Germany, which appears to be the only country of the group that, although structurally a net exporter, successfully managed to remain 'palatable' to foreign investors. A positive balance is also shown by France, while Great Britain, in spite of the above mentioned changes, remains a net recipient along the decade.

Table 8: Motor vehicles revealed transnational advantages

	Early 80's		**Early 90s**	
	absolute	symmetric	absolute	symmetric
France	...	...	0.78	-0.12
Germany	1.74	0.27	1.61	0.23
G. Britain	0.46	-0.37	0.33	-051
Italy	2.52	0.43	0.81	-0.10

Although quite interesting, and more or less well known, the results we have just presented suffers from a limitation, as they do not consider the different scale of the FDI activities of the various countries. For this reason, in order to obtain more significant results, it is opportune to normalise the previous indicator with respect to the relative weight of the World FDI outward stock in the motor vehicles sector, that is, the denominator of the previous equation. In so doing, a proper revealed transnational advantages/disadvantages indicator can be obtained, whose meaning is the same of the previous ones: values greater than one (or positive, if the indicator is symmetric) denote that country i has a transnational specialisation in sector j (in this case the automobile sector), while the reverse holds for values between 0 and 1 (or negative, in the symmetric version).

Unfortunately, the data to obtain the denominator of the RTNA are difficult to obtain. As

data on both the automobile and the total outward FDI stocks are not available for all the World countries, and for the same periods, a 'second best' solution is to work out the specialisation/despecialisation index with respect to a more circumscribed area (the OECD countries) and to wide temporal references (such as the early '80s and the early '90s), encompassing years that, although not coincident, are close enough between them.[18] With these caveats in mind, the RTNA indicators in the automobile sector of the four countries of our sample are reported in Table 8.

Quite differently from the previous figures, the computation of the RTNA indicators shows a more composite picture. In the first period, Italy is the most specialised country in the automobile sector. However, it experiences a very sharp drop in the early '90s, when it is overcome by Germany, for which, in turn, the indicator remains more or less stable, suggesting a persistent specialisation. To be sure, Italy is the only country for which, again, a structural change occurs, from specialised to slightly despecialised. This is certainly due to the very low level of the denominator of the RTNA formula, and thus simply expresses the irrelevance of the rest of the economic sectors with respect to the automobile sector, in terms of FDI. Therefore, the large decrease of the indicator seems to be due more to the internationalisation of the Italian economy as a whole, rather than to an absolute weakening of the automobile sector.

Great Britain, as expected, has the lowest values, and is the only despecialised country in the early '80s. France, for which data are available for the last period only, is characterised by a despecialisation with values almost equal to those of Italy, but with an underlying structure of the FDI completely different.

6 Conclusions

In this paper the structure of the automobile industry has been analysed from a system perspective. Given the importance of the techno-economic interrelationships which establish between this and other sectors, both inside and outside a certain economy, the concept of technological system has been used as unit of analysis to investigate the innovative process of the motor vehicles.

By examining the characteristics of both production and innovation flows, both intersectoral and international, we have tried to determine the extension and the most important features of the automobile TS of the four biggest European markets (i.e. France, Germany, Italy and Great Britain) in the last decade.

[18] To be sure, the World of reference we have retained for our calculations is a subset of the OECD countries. However, the countries for which data are not available are presumably not very important in terms of outward FDI.

As the aspects we have addressed are quite numerous, and have been examined by using a set of heterogeneous analytical instruments (such as input-output theory, network techniques, specialisation analysis), the results we have obtained are manifold and difficult to be exhaustively synthesised. Some important conclusions can however be drawn.

The first set of conclusions refer to the importance of the sectoral TS as the unit of analysis. Indeed, fresh insights can be brought into the study of a very traditional industry such as the automobile industry.

Firstly, we have detected a very high degree of stability in the face of change. The various TS examined managed, more or less successfully, to maintain their stability by means of a high level of internal change. In fact, in front of an overall stability of the usual industrial indicators, our different levels of analysis have detected a sustained process of change in the various elements of the automobile TS, all of which contributed to a relatively steady path of development.

Secondly, 'scale effects' are very much evident for TS rather than for single producers. In this sense, notions such as "reverse salient" (Hughes, 1989) and "functional failures"(Constant, 1980) appear to be appropriate in the description of what has going on in the automobile industry in the decade we have examined.

Thirdly, the TS dynamics we have observed, are more varied and characterised by a high degree of structural change, than that characterising the single TS units. As we have noted, dynamic effects are very diversified. Different parts of the TS, with different relative dimension and weight, have undergone substantial changes along time. These changes were different among the various TS, but also, when they were more or less similar, the result was by any mean the same. Indeed, some of them were subject to structural change forced by the underlying process of diffused technological change, while for others the globalization played an important role, while, finally, for others it was the institutional change to trigger the evolution of the TS. For all the combination of the three was surely never the same.

Coming now to more detailed aspects, the following points are worth stressing again.

First of all, when internal techno-economic relationships are considered, the automobile industry shows some general sectoral properties (such as dominant backward linkages and innovative dependence) that hold in all the countries of our sample. However, the same characteristics apply to the four countries to a different extent, thus suggesting how the institutional set-up, within which a certain industry operates, might works as a differentiating element. For example, the French automobile industry relies on external innovations much more than the German one, whose pervasivity in turn contributes to make its national innovation system more connected. Further differences emerge when the specific nature of the techno-economic flows is analysed in more detail. In the case of Italy, for example, the automobile sector reveals an innovative dependent sector, unless innovation flows of small dimension are also considered, insofar catching the dense network of relationships which establish with small size specialised

supplier firms. When both small and large innovative flows are considered, instead, the Italian sector turns out pervasive, while the German automobile TS becomes the only one which gets innovations from traditional kind of sectors for flows of large magnitude.

Secondly, temporal aspects are also very relevant in analysing (internal) intersectoral relationships. Indeed, along the retained period, apparent divergence phenomena can be found by looking at proper innovative indicators. The progressive increase of the (total manufacturing weighted) R&D expenditure, and of the revealed (by patents) technological advantage of the German motor vehicles, as opposed to, respectively, a less substantial increase and a decrease in France and Great Britain, is the most relevant example. Although cyclical factors also intervene in explaining these results, as it is apparently shown by the irregular trends of the Italian TS, more structural kind of changes can also be detected. A significant example is provided by the British motor vehicles, with respect to which the well-know recent pattern of internationalisation has brought a very substantial decrease of its production backward linkages and of its innovative dependence. In this case therefore, it is the evolution undergone by the relative innovation system in a climate of globalization to have entailed a change in the sectoral characteristics of the automobile industry.

Finally, interesting results have been also obtained by looking at the international relationships of the automobile TS. As far as export flows are concerned, a part from the uncontested dominance of France and Germany on the European market, the countries considered reveal different patterns of specialisation in different geographical areas. In spite of some recent changes, the Italian automobile industry, for example, appears relatively more successful in the penetration of developing countries, while Germany reveals more specialised in Japan and USA.

A similar argument holds when foreign direct investments are considered. On the one hand, automobile companies are among the most multinationalised in all of our countries, both in terms of transnational subsidiaries abroad and of hosted foreign affiliates. On the other hand, inward FDI are more relevant than the outward in some countries (such as Great Britain), while the reverse holds in some other (for example, Germany). Country specific effects can also be identified by looking at the temporal changes of both inward and outward FDI, which are in general decreasing from the early '80s to the early '90s. Hence, for example, the sign of the FDI balance, and of the relative outward specialisation, changes significantly in the case of Italy, which turns from a net exporter to a net FDI recipient.

Although many other important aspects have been left out from the analysis, which could therefore be integrated in several respects (in particular organisational), the results obtained are quite interesting. Indeed, they suggest how the relational and contextual elements which are caught by the notion of technological system are among the factors which explain the different national performances of the European automobile industry. In other words, the automobile technological system reveals properties that, although idiosyncratic, induce different innovative

outcomes, depending on their matching with different institutional set-ups, which are sectoral but also, and especially, national. Different systemic approaches should therefore be considered as complementary, rather than substitute or even contrasting.

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Appendix

A.1: Backward/Forward Linkages indicators: sectoral disaggregation

1	Agriculture, forestry & fishing	16	Electrical apparatus, nec (incl TV)
2	Mining & quarrying	17	Shipbuilding & repairing (incl Other)
3	Food, beverages & tobacco	18	Motor vehicles
4	Textiles, apparel & leather	19	Aircraft
5	Wood products & furniture	20	Professional goods
6	Paper, paper products & printing	21	Other manufacturing
7	Industrial chemicals (incl drugs)	22	Electricity, gas & water
8	Petroleum & coal products	23	Construction
9	Rubber & plastic products	24	Wholesale & retail trade
10	Non-metallic mineral products	25	Restaurants & hotels
11	Iron & steel	26	Transport & storage
12	Non-ferrous metals	27	Communication
13	Metal products	28	Finance & insurance
14	Non-electrical machinery	29	Community, social & personal services
15	Office & computing machinery	30	Producers of government services

A.2: Pervasivity/Dependency and Network indicators: sectoral disaggregation

1	Food, beverages & tobacco	11	Metal products
2	Textiles, apparel & leather	12	Non-electrical machinery
3	Wood products & furniture	13	Office & computing machinery
4	Paper, paper products & printing	14	Electrical apparatus, nec (incl TV)
5	Industrial chemicals (incl. Drugs)	15	Shipbuilding & repairing (incl Other)
6	Petroleum & coal products	16	Motor vehicles
7	Rubber & plastic products	17	Aircraft
8	Non-metallic mineral products	18	Professional goods
9	Iron & steel	19	Other manufacturing
10	Non-ferrous metals		