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(Article begins on next page)
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Technical efficiency and productivity growth along the automotive Value Chain: evidence from Italy

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Abstract

We propose an empirical study on the Italian automotive sector during the 2007-2011 period, applying Data Envelopment Analysis and its robust version based on the bootstrap theory, in order to get estimates of the efficiency and productivity growth at firm level. We focus our attention on the position of the firm along the value chain, its size and its vertical structure, by distinguishing four different strategies of outsourcing. Our results highlight how the recent crisis has stimulated a strong process of re-organization and re-thinking of activities of the firms but, in particular, the crisis has increased the pre-existing heterogeneity, confirming an ample previous literature. On one hand, the technical frontier is driven by firms generating technology development which play essential roles in the automotive value chain. From the other hand, an increasing number of marginal firms (mainly micro and small ones, characterised by a high level of vertical integration) are not able to play the same game. The result is an increasing unbalance of the automotive production system, confirming a sort of “neo-dualism”, with two groups of firms, leaders and followers, characterised by a rising distance in term of efficiency levels and productivity growth.

Keywords: Value chain, DEA, Vertical integration, automotive.

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1. Introduction

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During the last decade, the increasing complexity of production processes and the increasing possibilities of integration among firms and products fostered the development of the so-called Global Value Chains (GVC). GVCs are mainly based on the idea of a modular production network (Brusoni and Prencipe, 2001; Sturgeon et al., 2008) as a form of industrial organization in a high and medium tech industries, that can be partially applied to the automotive sector. In fact, this industry exhibits some characteristics of modular networks even though it maintains important features of a captive network, with some limitation of suppliers’ competition due to the absence of open, industry-wide standards and to specific features of technology which are tightly controlled by carmakers or assemblers (Frigant, 2013). In this view, the whole production system can be seen as a network where suppliers and buyers, sometimes with comparable dimensions, interact without a pre-defined market power on one of the two sides (Sturgeon, 2002). As a consequence, firms show different degree of vertical and horizontal specialisation, producing different parts of the final goods within the value chain. The main players (carmakers) remain at the top of the chain conceiving the product, designing, branding and selling it, with a low degree of vertical integration, often buying standardized components (or less standardised) from other large (or small) companies (Sturgeon et al., 2009). This industry structure enhances innovations, shares the benefits of efforts in exploiting technologies, reduces transaction costs, and protects sellers from idiosyncratic demand shocks (sudden reductions of orders affecting only some customers) as pointed out by Kranton and Minehart (2001). However, it introduces an additional source of heterogeneity for firms adopting comparable or complementary technologies, which are incremental in respect to the traditional source of differentiation across firms highlighted by the capability-based theory (Teece et al. 1994). On one hand, a hierarchy based on the specific activity made by each firms, emerges within the network: some activities show higher technological contents than other, or give higher market power. From the other hand, the direct relationship whit carmakers create another hierarchy based on the bipartition between direct and indirect suppliers (Castelli et al., 2011). Moreover, the recent automotive value chain is organised as a multi-tier supply chain, where only a certain number of firms, in many case multinationals affiliates, shows direct relationship with carmakers (tier-1 suppliers), while a large number of other firms plays as tier-2 or tier-3 suppliers, with the possibility of supplying different actors of the value chain (Schmitt and Van Biesbroeck, 2013). Therefore, the relevance of heterogeneity among companies, operating at different tiers, increases and influences the interactions among agents with mechanisms which make the system self-
organizing. Observable heterogeneity in profitability and growth is driven by the heterogeneity in efficiency and productivity levels due to the quality of inputs, the R&D levels, the innovation strategies, the activity specificities, size and idiosyncratic organizational capabilities (Dosi et al., 2010). Similarly, Bottazzi et al. (2010) found that heterogeneity in efficiency levels primarily yields persistent profitability differentials, whereas the relationship between growth of the firms along with their productivity or profitability appears much weaker. In this respect, the value chain analysis, aimed at identifying the activities in which firms operate, is a powerful tool to detect one of the sources of differences among firms and gives some additional instruments to interpret them. The identification of the main nodes of the chain allows to discover the role of the firms in the production process, without assuming a specific shape of the value chain. Even if the term *value chain* suggests a sequence of activities ending with the final product, a car in our case, the organization of the production process is better described by a network, where nodes represent specific activities interacting each other’s without a pre-assigned order. The specificities of each activity, in terms of technology, assets specificity and market structure influence the size of the firm and the make or buy choice. In fact, Monteverde and Teece (1982) found that higher degrees of vertical integration in the automotive industry are more likely when the assets specificity is high; evoking that firms involved in relational value chain could be more integrated. Moreover, Bigelow and Argyres (2008) highlight, that make or buy choice is strongly dependent from the level of transaction cost, which are different for different size class and activity, allowing for smaller efficient size when modularity apply, in contrast with the increasing minimum size, characteristic of a relational network. The investigation of those aspects (i.e. activity within a specific value chain, vertical boundaries and size), their interaction, their influence on firms’ efficiency level and productivity growth are the main object of the present study.

Furthermore, the relationship between value chain characters and efficiency/productivity performance of firms has been scarcely investigated by the literature, specifically with regard of, the effect of size, and vertical boundaries of the firm.

In this framework, our study is focused on the automotive value chain, particularly important in Italy for the high number of small and medium firms involved and the large number of workers employed. The higher focus represents a limit in comparison to previous studies (Dosi et al., 2012; Bottazzi et al., 2010; Bottazzi et al., 2007) that investigate labour productivity dynamics across all Italian manufacturing sectors, at least in terms of results interpretation. However, a higher homogeneity of the sample allows highlighting specific trends which characterise the
automotive industry and its firms.

Finally, the issue of productivity changes during the crisis has been investigated more deeply than previous work by applying non-parametric methodologies (i.e. Data Envelopment Analysis), for the measurement of technical efficiency levels, using the more recent results of bootstrap. Moreover, the application of Malmquist indexes within the DEA framework, leads to the identification of Total Factor Productivity (TFP) changes, and isolates the pure technical progress occurred during the downturn.

The aim of our analysis is twofold. On one hand, we investigate the existence of some regularities between performances, in terms of technical efficiency, to confirm the advantages of being specialised in certain activities along the value chain, highlighting where firms can show technical advantages in combining inputs for the nature of specific activity along the production processes, having also in mind the importance of vertical strategies and specific scale effects. On the other hand, we analyse the TFP changes, across activities and across groups, showing the consequences of the crisis in terms of pure technical progress and efficiency recovery. In particular, this part of the work highlight the increasing heterogeneity, in term of productivity performance, already identified by Dosi et al., (2012) and Bugamelli et al., (2010) as consequence of the Euro introduction, but now induced by the recent crisis.

The remainder of the paper is organized as follows: section 2 briefly reviews the relevant literature, section 3 describes the DEA model, the bias correction procedure and Malmquist indexes, section 4 presents the dataset, section 5 illustrates our results and, finally, some general considerations conclude the work.

2. Literature review

2.1 Value chain, vertical integration and productivity

The analysis of value chains has been increasingly applied to industrial economics and it assume the existence of a hierarchical set of firms linked at different levels of a production process ending with a final product (Gereffi et al., 2005). Market power is unevenly distributed in vertical links (relations between suppliers of different layers) and even in horizontal links (relations between suppliers on the same layer). However, beyond the traditional notion of power defined as the capacity of pricing over marginal cost, what matters in modern value chain analysis is the ability to influence technology and product characteristics, starting with the projected final results and involving also the intermediate components which deeply influence both performance and quality appreciated by the
customers.

Three types of value chain are often discussed, defined by the predominant kind of governance. On one hand, captive networks are characterised by a high ability to codify technology in the form of detailed instructions, a wide complexity of product specifications, but low supplier capabilities. From the other hand, relational networks show product specifications which cannot be codified, transactions are complex and supplier capabilities are high. Finally, modular networks imply a more developed and competitive market, given the ability to codify and share technical specifications also for complex products: in this situation suppliers have the competence to supply full packages and modules that can be easily integrated in the final product (Gereffi et al., 2005).

As previously highlighted by Monteverde and Teece (1982), the organization of the value chain deeply influences the observed level of vertical integration, mainly through the moderating effect of transaction costs which also differ for size class of the firms (Bigelow and Argyres, 2008). Moreover, according to the competence-based approach to the theory of the firm, vertical integration is mainly determined by the co-evolution of specific capabilities, the structure of the industries and the size of the market; this can induce labour division and allow for the entry of new specialized firms. Nevertheless, according to Malerba et al. (2008), vertical integration is the result of a specific strategy and not only the outcome of the nature and distribution of transaction costs along the supply chain.

Some additional hints can be drawn by the model proposed by Van Assche (2005) based on the distinction among ideal outsourcing (each supplier sells to a specific final firm), standardized outsourcing (the burden of customization of components falls on the buyer) and customized outsourcing (when the burden falls on the seller, who adopts flexible manufacturing equipment). Unfortunately, specific information needed to clearly classify suppliers cannot be easily collected, thus one possible way to analyse the value chain is by classifying the technical relevance of main nodes, represented by macro-activities. Furthermore, the intensity of outsourcing is traditionally measured in literature by vertical integration indicators, based on ratio between added value and total revenues (Adelman, 1955) or on the share of external costs over total production costs (Calabrese and Erbetta, 2005).

The vertical structure is an important factor influencing technical efficiency of firms through the increasing focus on core activities, for which their ability should be higher. The debate on the relationship between the choice of outsource production phases and efficiency or productivity has been largely discussed by different authors with unclear emerging evidence, both under theoretical and empirical points of view. First of all, different levels of vertical integration can
exist in equilibrium, as highlighted by Elberfeld (2001), with different outcomes regarding performances.

Heshmati (2003) argues that vertical disintegration strongly depends on outsourcing decisions and that it is one of the strategies pursued by manufacturers to increase productivity through outsourcing services often characterised by low TFP growth, aiming at reducing labour cost, and enhance flexibility. On one hand, insourcing implies higher organizational and coordination costs (Grossman and Hart, 1986), but it allows a saving in terms of marginal cost as stated by Elberfeld (2001). Moreover, integrated firms can also benefit from greater coordination along the production chain (Kogut and Zander, 1996), avoiding higher prices for inputs due to double marginalization in an imperfect market (Perry, 1989). On the other hand, disintegrated firms pay higher transaction costs, but can better exploit their core competences, obtaining a higher level of efficiency in their activities (Kogut and Zander, 1996). On the empirical side, Girma and Görg (2004) found that in chemical and in engineering industries, outsourcing is related positively with labor productivity, whereas it does not seem to influence the productivity of plants operating in the electronics sector.

Focusing on the relationship between technical efficiency and vertical integration, the literature is scarce and the results are controversial. Mansson (2004) find no evidence on the relationship between vertical integration and productivity for Swedish sawmills applying a DEA approach, while Pieri and Zaninotto (2013) studying the machine tool industry, found that vertical integrated companies present a lower inefficiency level than disintegrated companies, even after controlling for other characteristics. Therefore, vertical integrated firms appear more efficient in the machinery industry than disintegrated firms, even though it could be the result of a self-selection mechanism inducing more efficient firms to vertically integrate activities as an outcome of detailed strategies aimed at the control of the production chain.

2.2 The Italian automotive value chain: a peculiar case

Previous studies on the automotive industry highlight that the level of vertical integration appears direct or indirect consequence of the value chain organization and strictly linked to the hybrid organization of the chain, partially captive and partially modular as argued by Sturgeon et al. (2009). The Italian automotive value chain has been defined in different ways in the last three decades. In the 1960s and 1970s has been called induced automotive activities or, even better, induced Fiat activities to indicate a situation in which the suppliers were strongly dependent on Fiat. In the 1980s and at the beginning of the 1990s, the automotive suppliers were firstly defined as a system, in order to stress structural interdependencies among all the firms in the supply chain and recently as a
Nowadays, the worries regard, above all, the entrepreneurial ability of the automotive suppliers to compete with the world-wide players without the traditional filter offered by Fiat, the local champion, involved in an intense restructuring process and a strong integration with its American partner, Chrysler. In this context, the issue of becoming important node along the GVC is more than a mere opportunity, it is essential for the survival of the firms (Giunta et al. 2012). The Italian automotive sector is characterised by a large number of small and medium firms as well as by the local plants of large multinational companies, all localized near the production sites of the national champion. However, during the last decade, many firms had to reconsider their role in order to acquire an increasing degree of independence from their main customers and thus contributed to developing a new shape of the value chain (Castelli et al. 2011). In 2012 the Italian automotive supply chain generated a turnover of 38 billion Euros and employed a total of 179,000 workers, but the industry is still characterized by small size and high production fragmentations: small firms with less than 50 employees are about 75% of the total (STEP, 2012). Of course, this might be a weakness, because small firms are generally less innovative than medium-large sized firms and production is concentrated in a few areas, 40% of the manufacturers are located in the Piedmont region (Manello, 2012). The level of diversification towards other sectors is quite low: on the whole, 80% of sales are directed to the automotive sector and 35% to the sub-suppliers (Calabrese, 2011). Nevertheless, diversification changes across the various regions: it is higher in Emilia-Romagna, where companies focus not only on the automotive, but also on the motorcycle and agricultural vehicle sectors, as well as other sectors (Bardi and Calabrese, 2007), while it is lower among the Piedmont companies which mainly manufacture for the FIAT Group. The distribution of actors along the Italian automotive value chain, according to their main areas of specialization, is: providers of materials and minor mechanical works (sub-suppliers, 52.0%), manufacturers of parts (components, 30.0%), manufacturers of modules or systems (6.0%) and providers of design and engineering services (12.0%). Most of the module and system suppliers are multinational companies which have purchased plants from large domestic suppliers and adapted them to the tiered production system launched by FIAT (Calabrese and Enrietti, 2013; Rolfo and Vaglio, 2009). Currently, their dependence on FIAT Auto has decreased and they are selling to other carmakers through their affiliated companies; consequently, many module and system suppliers seem to have downsized or closed their local R&D centers, as research is carried out directly at their headquarters. The components manufacturers and sub-suppliers operate in a context of incremental innovation, which is typical of mature technologies, where the innovation process proceeds over time along a logistic curve. Innovation is not a structured activity for
these firms; rather, it is incremental, occurring on a daily basis and involving all the aspects of the company. Nevertheless, the technological sophistication of component suppliers has constantly increased in order to meet the needs of their customers. In the past they only provided generic materials, whereas they now tend to produce highly specialized products.

3 Methodology

3.1 The efficiency model: bootstrap and bias corrections

In the present paper we have adopted a fully non-parametric Data Envelopment Analysis approach to compute efficiency scores of a large sample of Italian firms operating in the automotive industry. The main advantage of using DEA is that it does not require the specification of a form for the technology representing the production process and therefore, no assumptions have to be made on the shape of the production frontier. Moreover, DEA allows for the computing of simple inefficiency measures also in the case of multi-output and multi-input underlying technology: the frontier is directly derived from data and all the firms in the sample are evaluated through distance functions.

However, the main disadvantage of this deterministic approach lies in the absence of an error component: all the departure from the estimated frontier is detected as inefficiency without considering the possibility of stochastic disturbance. DEA methodology has been widely used since the 1980s to assign technical efficiency scores that can be analysed using non-parametric techniques. For a detailed treatment of the DEA model see Cooper et al. (2007), while a first application of DEA to value chain analysis in the automotive industry can be found in Saraga (2009).

The framework can be input or output oriented. The input-oriented framework, based on the input requirement set and its efficient boundary, aims at reducing the input amounts by as much as possible while keeping at least the present output levels. In this approach, output levels remain unchanged and input quantities are reduced proportionately till the frontier is reached. This is generally the orientation adopted by the decision maker that can control inputs but not outputs at all.

According to these considerations, an input oriented framework has been used here, assuming constant returns to scale (CRS) on the basis of the Charnes et al. (1978) model. The technical efficiency scores, $TE_i$, are then computed by solving, for each firm in the sample, the following linear problem:

$$
TE_i = \text{Min} \quad \theta \\
\text{st:} \quad -\theta x_i + X\lambda \leq 0 \\
y_i - Y\lambda \leq 0 \\
\lambda \geq 0 \\
0 < \theta \leq 1
$$

(1)
Where $\lambda$ is a vector of $nx1$ weights allowing convex combination of inputs and outputs, $Y$ is an output matrix, $X$ is an input matrix; $y_i$ represents the “$i$” output of the firm, and $TE_i$ the inverse of the corresponding Total Factor Productivity index. Furthermore, $1-\theta$ presents the proportional feasible input reduction, maintaining constant output levels.

Obtained $TE_i$ $(i=1,2,...n)$ take the unity value if no contractions of inputs are technically feasible, then the firm is on the best practice frontier. A value of efficiency scores less than unity represents the possibility of cutting inputs, maintaining the output level unchanged. In the present paper the homogeneous bootstrap procedure, described in Simar and Wilson (1998), is applied to correct deterministic estimates for the potential bias due to finite sample. This causes an effective impossibility to observe the unity values, due to the quasi-stochastic nature of the frontier; for a detailed discussion of the methodology, see for Daraio and Simar, (2008).

### 3.2 Malmquist indexes: a way to compute TFP growth rate

The results from DEA cannot be directly compared in order to obtain the change in the Total Factor Productivity (TFP) levels, because the reference frontier changes each year and then efficiency scores represent the departure of each firm from the yearly specific frontier. In fact DEA scores represent a static proxy of the technical efficiency level reached by each firm in each specific year; however nothing can be said of the productivity trend that could be very useful to interpret the firm growth potential in the future. A measure of TFP growth can be derived from the idea of Malmquist indexes combining the yearly frontier information from DEA scores (Färe and Grosskopf, 1996 provide additional detail). To calculate the TFP growth, output to input ratios (used in the standard productivity approach) are replaced, at each time, by efficiency scores obtained from separate estimates of best practice frontiers. Therefore, following the Malmquist approach and taking ratios of distances based on both $t$ and $t+1$ frontier, an indicator of TFP change can be derived within the DEA framework. In notation:

$$M_{t,t+1} = \left[ \frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^{t}(x^{t},y^{t})} \right]^{\frac{1}{2}} \left[ \frac{D_o^{t+1}(x^{t},y^{t})}{D_o^{t+1}(x^{t+1},y^{t+1})} \right]^{\frac{1}{2}}$$

Where $D_o^{t}(x^{t},y^{t})$ and $D_o^{t+1}(x^{t+1},y^{t+1})$ are output distance functions, computed through standard DEA models, at time $t$ and $t+1$ and the other two components are obtained as solutions of mixed period linear programs where the input-output mix at each time is compared with both the frontier relative to $t$.
and \( t+1 \). Following Färe and Grosskopf (1996), the graphical representation can help the interpretation of indexes using segments on the graph (figure 1), as reported in the second part of equation (2).

**Figure 1. Malmquist productivity indexes and their decomposition**

![Graph](image)

TFP growth will result in values of \( M^{t,t+1} > 1 \), while \( M^{t,t+1} < 1 \) represents deterioration in the total factor productivity level, which can be easily observed during periods of economic downturn. Moreover, Malmquist productivity indexes are often used to separate the effect due to efficiency recovery between period \( t \) and \( t+1 \) from the pure frontier shift, which together determine the TFP changes. The first represents the catching up effect and can be seen as the reduction (increase) of the relative distance to the frontier in the next period. The second reveals the technical progress which occurred during the two periods and can be seen as the movement of the frontier over time. Generally this term is assumed to have a strictly positive impact on TFP, even if this condition is not always verified during a deep crisis.

Graphically, it becomes clear that this last term, the frontier shift, can be measured, taking as reference, two inputs bundles, the one related to time \( t \) or the one related to \( t+1 \), while the efficiency components can be represented by the ratio between the distance to the frontier in \( t \) and in \( t+1 \).

\[
EFF^{t,t+1} = \frac{0e}{0f} = \frac{0a}{0b} \quad \text{TECH}^{t,t+1} = \left[ \begin{array}{c}
0d \\
0b
\end{array} \right] \left[ \begin{array}{c}
0f \\
0c
\end{array} \right]^{\frac{1}{2}}
\]  (3)
Both components can be written as the ratio of segments referred to the graph in figure 1, like in equation (3), but it can also be re-formulated in terms of output distance functions and computed according to DEA linear programs (eq. 4).

\[ M_{t,t+1}^{\text{EFF}_{t,t+1}} \cdot TECH_{t,t+1}^{\text{EFF}_{t,t+1}} = \frac{D_{t}^{\text{EFF}_{t,t+1}}(x^{t+1}, y^{t+1})}{D_{t}^{\text{EFF}}(x', y')} \left[ \frac{D_{t}^{\text{EFF}_{t,t+1}}(x^{t+1}, y^{t+1})}{D_{t}^{\text{EFF}}(x', y')} \right]_{-1} \right]_{-1}^{1} \]  (4)

The two components represent the two different sides of technical TFP improvement: the EFF term represents the “learning by doing” process which occurred between \( t \) and \( t+1 \), then the higher capacity of firms to exploit the available techniques at \( t+1 \) relative to the technology pictured by frontier at time \( t \). This better utilization of existing technologies can lead to TFP improvement also in absence of technical progress through an increasing capacity in using available techniques. Otherwise, the TECH term represents the technical advancement between \( t \) and \( t+1 \) and it represents a pure technological progress effect, shifting the best practice frontier upwards and generating new techniques available.

4 Data

We collect data to build one of the most complete database representing the whole Italian automotive value chain by merging different data sources coming from previous empirical investigations made by Italian scholars (Garibaldo 2008; Morsa and Pirone, 2010; Volpato and Stocchetti, 2007; Enrietti et al, 2007; Calabrese and Erbetta, 2005).

The result can be considered as an accurate representation of the total population of firms located in Italy and operating in the automotive value chain, including 4,207 firms. The main differences, in comparison to previous surveys, consist in how the value chain is defined and which kinds of companies are considered. The starting point is made up of 72.6% limited-liability companies and 27.4% unlimited-liability companies, but the needed of balance sheet data restrict the sample to limited-liability companies, included in the Aida database of Bureau van Dijk. The additional requirements of complete balance sheet data over the considered period (2007-2011) and the necessity of observing firms active both in 2007 and 2011 reduce the number of companies included in our analysis. In particular, firms that go into bankruptcy during the crisis or new firms created after 2007 are excluded by the sample, but the spatial representation has been preserved since regional differences between the initial and the final sample are negligible.

4 The automotive value chain can be understood as including only companies whose core business is directly connected to car products or extended to companies belonging to functional sectors too.

5 The Aida database mainly contains financial data on limited companies. Companies which are no longer active are included as well.
Our attention is entirely focused on firms operating in the automotive value chain, therefore large assemblers (systems integrators) such as Fiat, New Holland or Iveco has been excluded from the sample, but their entire group of first, second and third tiers suppliers are included: the final sample is composed by 1550 firms. The main objective of the present work is not to analyse short term dynamics, deeply influenced by contingent factors, but it is the understanding of the medium and (partially) long term effect of the crisis on efficiency and productivity levels. The worst phase of the crisis in Europe, at least in the automotive sector, started in 2008 continue in 2009, while a partial recover started in 2010 and 2011, coming back to the previous horizontal trend. The same occurred in the rest of the world, as depicted by figure 2, which compares car production in Europe, the relevant market for Italian suppliers, and the whole world. Considering 2007 as a pre-crisis observation and 2011 as a crisis observation allows us to identify the actual outcome of the crisis, net of short term recoveries (2010) and lowest peaks (2009).

Figure 2: Production trends of passenger cars and commercial vehicles (millions of units)

![Production Trends Graph](http://www.oica.net/category/production statistics/)

Going back to the production process described in the DEA model, the firm is defined as a black box combining three inputs to obtain one monetary output, which is represented by the production value, the sum of turnover and working in progress contracts, net of inventory changes. The inputs considered represent the amount of fixed capital used in the production process, labour and intermediate goods. Capital has been defined by net technical assets from the balance sheet, while intermediate goods are represented by the total amount of services and goods purchased during each
year, net of inventory changes. The labour input, for which the quantity of hours worked are the best proxy, has been measured by the labour costs, more precise and reliable because they are included among balance sheets variables.

In table 1 we present the distribution of the samples according to the role of firms in the value chain in terms of prevalent activity done, representing the position along the automotive value chain, with the average input-output data for each group. It is not possible to separate resources used in activities directed to production outside of the automotive sectors, however, all firms included in the sample are mainly focused on automotive customers. In terms of activity, firms operating in metals and components are more numerous, and especially in metals we can expect a larger proportion of Small and Medium Enterprises (SMEs) as suggested by the lower average inputs and outputs.

Table 1. Composition of the value chain and average input - output values, 2011

<table>
<thead>
<tr>
<th>Sectors</th>
<th>No. of firms</th>
<th>Input</th>
<th></th>
<th>Output</th>
<th></th>
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<tr>
<td></td>
<td></td>
<td>Technical assets (000s €)</td>
<td>Intermediate goods (000s €)</td>
<td>Labour costs (000s of €)</td>
<td>Production (000s €)</td>
</tr>
<tr>
<td>Metal</td>
<td>134</td>
<td>2,899</td>
<td>13,802</td>
<td>3,715</td>
<td>24,214</td>
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<td>Machinery</td>
<td>422</td>
<td>2,800</td>
<td>7,546</td>
<td>2,483</td>
<td>14,829</td>
</tr>
<tr>
<td>Plastic and rubber</td>
<td>112</td>
<td>4,065</td>
<td>14,537</td>
<td>4,276</td>
<td>25,930</td>
</tr>
<tr>
<td>Mechanic Components</td>
<td>775</td>
<td>3,716</td>
<td>14,101</td>
<td>3,816</td>
<td>23,743</td>
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<tr>
<td>Electronics</td>
<td>113</td>
<td>4,960</td>
<td>20,816</td>
<td>5,554</td>
<td>35,027</td>
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<tr>
<td>Total sample</td>
<td>1,556</td>
<td>4,120</td>
<td>11,324</td>
<td>3,594</td>
<td>20,022</td>
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</tbody>
</table>

We cannot clearly observe the prevalence of SMEs in certain chain nodes from the simple analysis of average size in terms of revenues, assets or labour utilisation, because the conclusions can be misleading. Therefore, we assign a size class to each firm, adopting the European classification and we compute, for each activity, the share of firms in each class: small enterprises (micro and small firms) represent the 65% of the total sample, but a higher share in the Mechanic Components and Design, both near 70%.

Table 2. Distribution of the sample according to value chain nodes and size (average 2007-2011)

<table>
<thead>
<tr>
<th>Firm size</th>
<th>Value chain nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mechanic Components</td>
</tr>
<tr>
<td>Micro</td>
<td>31%</td>
</tr>
<tr>
<td>Small</td>
<td>39%</td>
</tr>
</tbody>
</table>
Finally, we have computed the vertical integration indicator proposed by Calabrese and Erbetta (2005), using the reverse of the external cost over total cost ratio, and we have divided the sample into 4 categories, identified by different make/buy strategies. Using the quartiles of the computed index as thresholds, we have identified firms with a high vertical integration (disintegration) and those with an intermediate integration (disintegration). Table 3 reports the distribution of the firms according to their vertical strategies and their size class.

Table 3. Vertical integration strategies using vertical integration quartiles values (average 2007-2011)

<table>
<thead>
<tr>
<th>Make of Buy strategy</th>
<th>Firm size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro</td>
</tr>
<tr>
<td>Highly Deverticalized</td>
<td>12%</td>
</tr>
<tr>
<td>Deverticalized</td>
<td>16%</td>
</tr>
<tr>
<td>Integrated</td>
<td>24%</td>
</tr>
<tr>
<td>Highly Integrated</td>
<td>49%</td>
</tr>
</tbody>
</table>

Micro and small firms show a higher propensity to insource while larger firms tend to outsource more frequently part of the production processes, then we can conclude that vertical integration prevails in small businesses, while de-verticalization is a character of medium and large firms.

The analysis of vertical integration level across the activities of the value chain, showed in table 4, highlights interesting path and differences due to intrinsic technological differentials.

The choice of make or buy seems relatively neutral for the production of Mechanic Components, with firms substantially equi-distributed across groups, while differences appear in Electronics, with a 35% medium-high level and a small share of highly integrated (17%). Firms operating in the Metal industry are more frequently integrated (33% on average) with a smaller share of highly deverticalized (18%), on the contrary outsourcing seems to prevail in Plastic and Rubber and Machinery (29% and 28% low and medium low integration).

Table 4. Vertical integration strategies along value chain nodes (average 2007-2011)

<table>
<thead>
<tr>
<th>Make of Buy strategy</th>
<th>Value chain nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mechanic Components</td>
</tr>
<tr>
<td>Highly</td>
<td>28%</td>
</tr>
</tbody>
</table>
Deverticalized
Deverticalized  26%  20%  29%  23%  28%  24%  
Integrated     23%  35%  26%  26%  26%  24%  
Highly Integrated 23%  17%  18%  33%  17%  23%  

5 Results

Linear problems, as written in (1), are solved for each firm and for each year (2007-2011) using the R software, while the bootstrap procedure by Simar and Wilson (1998), is applied using the routines in the FEAR6 package. Outliers are detected using the Wilson (1993) outlier detection methods, and to refine results, only bias corrected efficiency scores have been considered in the final results.

The estimated efficiency scores come from a unique frontier, where all the firms involved in the automotive sector have been considered adopting the same technology. Of course this assumption appears too restrictive in some cases, mainly when the real production processes underlying some particular components are a bit far from one another, but at the first stage of the work our aim is to evaluate the differences in technical efficiency among activities in the value chain. However, this kind of results is more difficult to interpret when DEA scores are used to evaluate the Malmquist indexes: TFP change indicators are more sensible to the technological differences across the sample. In that case, the sample has been separated according to the specific activities along the chain to compute Malmquist indexes separately for each sub group. Therefore, the obtained estimates of technical progress and efficiency recovery showed in section 5.2 are specific for each sector without any contamination of potential source of productivity growth coming from the improvement in technologies from different activities.

5.1 Efficiency results along the value chain, size and vertical strategies

The first step in examining results is an assessment of the supposed correlation between the technical efficiency performances and the positions of the firms along the value chain. Actually the power and the relevance of each role can be suggested through the technological level of production activities, and this leads to the investigation of the points of strength and weakness in the network of links defining the chain. This topic partially goes beyond the objective of our study in which we only describe the distribution of technical efficiency, computed through DEA, for the main activities that characterise the

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automotive sector. In any case, the results from the solution of linear program (1) are reported as arithmetic means over each category in table 5, reporting values for the year before and during the crisis. While we interpret results it is useful to remember that efficiency is a relative concept: the relevant changes observed between the two reference years, 2011 compared to 2007, do not directly show the variations of total factor productivity, but they reveal that the differences among the best and marginal firms have increased a lot during the crisis. This warning is important since the Malmquist index will show a less dramatic change in terms of average TFP change in comparison to the average increase in inefficiency from comparing performance in 2007 and 2011, because the underlying frontier changed during the two considered years.

Table 5. Efficiency scores with bias correction and bootstrap

<table>
<thead>
<tr>
<th>Value chain position</th>
<th>DEA scores 2007</th>
<th>DEA scores 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>0.492</td>
<td>0.357</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.526</td>
<td>0.384</td>
</tr>
<tr>
<td>Plastic and Rubber</td>
<td>0.523</td>
<td>0.409</td>
</tr>
<tr>
<td>Mechanic Components</td>
<td>0.486</td>
<td>0.350</td>
</tr>
<tr>
<td>Electronic</td>
<td>0.502</td>
<td>0.364</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>DEA scores 2007</th>
<th>DEA scores 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>0.383</td>
<td>0.254</td>
</tr>
<tr>
<td>Small</td>
<td>0.480</td>
<td>0.338</td>
</tr>
<tr>
<td>Medium</td>
<td>0.594</td>
<td>0.451</td>
</tr>
<tr>
<td>Medium Large</td>
<td>0.610</td>
<td>0.527</td>
</tr>
<tr>
<td>Large</td>
<td>0.622</td>
<td>0.466</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Make or buy strategy</th>
<th>DEA scores 2007</th>
<th>DEA scores 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Deverticalized</td>
<td>0.594</td>
<td>0.451</td>
</tr>
<tr>
<td>Deverticalized</td>
<td>0.540</td>
<td>0.411</td>
</tr>
<tr>
<td>Integrated</td>
<td>0.474</td>
<td>0.345</td>
</tr>
<tr>
<td>Highly Integrated</td>
<td>0.365</td>
<td>0.229</td>
</tr>
</tbody>
</table>

Before the crisis (2007), Plastic and Rubber and Machinery were the activities with the lower level of inefficiency (respectively 0.523 and 0.526) while Mechanic Components (0.486) and Metals (0.492) had the worst performance. Remember that the indexes are DEA scores obtained in an input oriented approach: the values reported in table 5 are average “θ” obtained by solving the linear problems for each firm. Efficient firms near the frontier obtain scores close to unity.

The effects of the recent crisis have been particularly strong: the table suggests that the crisis stresses differences among firms: highly efficient firms show good ability in facing the new challenges from the
international crisis of the automotive sectors by diversifying their customers and their activities, but marginal firms do not have the internal resources to play the same game. The result is an increasing intra-sector heterogeneity, with the creation of two groups of firms following different growth and efficiency paths like in a sort of “neo-dualism”, already identified by Dosi et al. (2012) for a sample of Italian manufacturing firms. A small group of very dynamic and competitive firms, probably strong exporters, are able to define and drive the technology during the recent crisis, in opposition to a growing plethora of low-productivity firms which are becoming farer to the best practice frontier. The first group shows higher abilities in “doing things”, according to Teece et al. 1994, while the second shows difficulties in imitating best practice techniques, with lack of ability (or impossibility) in finding the right combination of action in doing things well. This kind of laggard firms are more numerous in activities such as mechanical components and metals, where many firms are less able to innovate and to follow recent developments in technology and managerial routines, remaining more disadvantaged in the recent global competition. In our case, activities linked to metals and mechanical components show a lower average efficiency level already before the recent crisis, highlighting a lower capacity in obtaining output per unit of inputs that is not contingent or linked to the downturn. Moreover, during the crisis they seem to pay the highest price: the strong increase in average inefficiency from 2007 to 2011 has been relevant and firms operating in mechanical components and metal become on average more and more distant to the best practice frontier, showing an increasing number of marginal firms producing minor components and metal parts using traditional technology. Those firms are more exposed to international competition due to re-localizations in low cost labour countries and during the recent crisis these they suffered a strong contraction of the demand from the local champion (FIAT). As shown for US manufacturing firms by Bernard and Jensen (2004) and Helpman (2006), marginal firms are not able to find other markets, with a consequent under-utilisation of their production capacity that causes dramatic efficiency cut-offs.

On the contrary, firms operating in the Plastic & Rubber and Machinery activities were, on average, less inefficient in both periods, then the adoption of best practice techniques is more frequent, or at least the average adopted technology is closer to the frontier. Electronic producers were near the bottom of the efficiency ranking in 2007, but worsened their position and performed similar to the less efficient groups in 2011, highlighting the difficulties in adopting high technology standards in this activity during the recent downturn.
The non-parametric Kruskal-Wallis test confirms that the differences observed among the different activities along the value chain are statistically significant at a 95% level of confidence. Graphically, these patterns are confirmed by looking at the shape of DEA score distributions, shown in fig. 3, where DEA scores (input oriented, where 1 is full efficiency) are plotted on x-axis and the cumulative share of firms is reported on y-axis, ordered by level of efficiency (first the ones with smaller scores). In all the cases, the distribution of efficiency scores shift to the left, in the direction of smaller scores, indicates lower efficiency in all the analysed activities, as the blue lines show on the graph. The difference between the two lines indicates the effect of the crisis: the Plastic and Machinery curves seem to be closer to the initial distribution relative to 2007, while the shift in Electronics seems wider. There is other evidence of decreasing technical efficiency in the graphs of fig. 1: a generalized change of the highest part of the line (better performing firms, up to 100% of the distribution), which moved to the left in 2011, indicating that even the better firms are less concentrated near the frontier. The Malmquist indexes will refine these first hints in the next paragraph.

The vertical integration strategy, defined using the quartile of the distribution of the Adelman index, play a significant role in relation to the technical efficiency performance. In our approach, if the level of vertical integration is neutral in respect to the computed efficiency scores, the average efficiency for the four identified groups (on the basis of vertical integration quartile) will
be similar. The Kruskal-Wallis non-parametric test confirms that the level of inefficiency changes significantly over the four identified groups, highlighting how firms adopting best practice techniques are more frequent among certain level of vertical integration. The relationship between vertical integration and efficiency is clear: the higher the level of vertical integration the higher the level of inefficiency. That evidence is stable during the period of crisis and confirms that the advantage of focusing on core competences through outsourcing exceeds the savings of transaction cost due to insourcing, as suggested by Cogut and Zandler (1996). In other words, during the downturn, the higher organizational and coordination costs of vertical integration overcame the advantages of higher coordination and lower marginal cost. The recent organization of automotive production as a global value chain has probably reduced transaction costs, while the growing pressure on technical efficiency and cost savings to remain competitive has stimulated an increasing focus on core competence. The best practice firms pursue the strategy of outsourcing less important activities which are committed externally, reducing their vertical integration but increasing their technical efficiency, as suggested by table 5.

Finally, considering firms dimension, micro and small firms are confirmed to be the most inefficient class (DEA scores of 0.38 and 0.48 in 2007), as is suggested by the branch of literature underlining the technical limits of small dimension for scale economies and R&D investments. The medium-sized firms seem to perform similarly to medium large and large ones, while the increase in efficiency standards is huge in comparison to small firms, highlighting a clear positive effect of size that is particularly strong moving from micro to small firms with an average differential of 0.10 score and from small to medium (0.11). Also in this case, non-parametric tests confirm the statistical validity of differences among groups built on size class.

Large firms are in general the most efficient, showing superior ability to define the best practice technology and save resources thanks to scale economies, but they also show more severe difficulties during the crisis. Being large represents an advantage in terms of technical efficiency, but during a crisis the rigidities due to the larger size overcome the advantage, as highlighted by the better performances of medium-large firms in 2011 in terms of average efficiency (0.53 versus 0.47). However, we notice that the medium size firms perform very similarly to large ones so that the technical level of these two groups looks very similar; the real jump remains from micro to small firms and from small to medium ones.

5.2 Total Factor Productivity growth: the role of value chain position, size and vertical strategies

The Malmquist productivity indexes measure the total factor productivity changes as a ratio between
the effective production and its maximum, feasible at the given technology with the same inputs mix, according to two estimated frontiers, one referred to 2007 and one to 2011. They take the form of index numbers, varying around unity: indexes smaller than 1 show a contraction of TFP, while indexes larger than 1 suggest a positive TFP growth. TFP is then decomposed into the efficiency growth indicator and the technical progress index according to the considerations from the methodological part.

In this case, having a unique frontier for firms with different productions along the value chain, represents a limit, mainly for the component related to Technical Progress which becomes hard to interpret: firms are partially heterogeneous and differences among them can partially derive by different technologies in use. In fact, TFP change computed through Malmquist strongly depends on the position of each single firm, compared with a mobile frontier that can be also defined by firms operating in different production phases. The approach based on one unique frontier as a benchmark like in the case of static efficiency analysis of section 5.1 can lead to a substantial overestimate of the technical progress component. In this case, the rate of change of technical progress is not only due to specific technology improvements related to specific activities, but to the entire set of automotive subsystem. However, in this way, a firm operating in a defined sub-activity can benefit from technical progress produced elsewhere, with a overestimate of the TECH component in equation 5. As solution of the problem, we evaluate the Malmquist index separately for each group defined by the specific activity, re-computing the best practice frontier once for each activity to obtain a more reliable and prudent TFP change estimates. In any case, we expect a strong impact from the recent crisis with contraction of global productivity on average for each group of firms analysed, and in fact TFP systematically shows a negative rates of change.

Table 6 collects the results from Malmquist indexes computation and the table shows average changes (columns 2-4) for each subgroup, calculated as a geometric means of individual firm value, while average annual growth rate in per cent are reported in columns 5-7 to make the interpretations clearer. Of course, given the construction of indexes, this value only represents the average yearly dynamics over the period, smoothing peaks caused by short term events.

Malmquist indexes show the peculiar role of technical progress in the Machinery industry, with the highest rate of technical progress (+12.7%), but a remarkable fall in efficiency; a result due to the presence of a small number of best performer firms able to contrast the crisis and pushing up the frontier significantly. The final outcome is the second best change in total factor productivity (-1.4%) among groups, that however highlight the most unbalanced composition within a specific activity.

The Mechanical Components group shows the worst performance, even if the role of technical progress is important at 5.5%, because it suffered a severe deterioration of efficiency (-7.6%) that prevail the
positive technical progress component: the result is the largest fall of TFP, around -2.5%. Similar consideration concern the Metal activity characterised by the third positive rate of technical change (2.2%), also in this case unable to contrast the contraction in the efficiency recovery term (-4.1%) that determine a drop in TFP around 2%. The crisis reduced capacity utilization and then it cut down not only efficiency but also the perceived level of potential output: this does not imply that the best disposable technology went back, but it is a typical case of overcapacity-driven negative productivity growth. **On the contrary, firms operating in Electronics face a best practice frontier that does not grow up on average during the crisis, but show a slight worsened suggested by the negative TECH component (-1.22%).** That situation allows a partial reduction of the TFP gap between followers and best practice firms, as shown by the positive EFF component (0.40): the result is the best performance in term of TFP, in reduction of only 0.83% for each year. Plastic and Rubber firms show a similar path with a similar weight of the TECH component (-1.33%), that is not counterbalanced by a positive efficiency recovery, with the results of a more negative TFP change. The non-parametric Kruskal-Wallis test confirms that the observed differences in TFP growth rates among value chain activities are statistically significant at a 95% level of confidence.

Analyzing the outcome in terms of TFP from the vertical strategy of the firm, Malmquist indexes highlight that the two extreme, highly integrated and highly deverticalized firms show the best performance, respectively -1% and -2% as average annual growth rate. Instead, the two intermediate strategies suffer a yearly reduction of -2.7% and -2.5% respectively, but in both cases the results are mainly driven by the negative role of efficiency change that exceeds the advantages of a positive frontier shift over time. By construction, the best practice frontier, for each activity, is driven by the best-performing firms, able apply best technology and to remain competitive also during the crisis. The rate of technical change appears in a positive relation with vertical integration, last column of table 6, with the expected opposite direction of section 5.1: most efficient firms in static term are in the highly disintegrated group and for them reaching TFP growth is harder.
Table 6: TFP growth indexes (2007 – 2011) and their components (6 frontier, 1 for each sector)

<table>
<thead>
<tr>
<th>Value chain position</th>
<th>Index Number</th>
<th>Average annual change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TFP</td>
<td>EFF</td>
</tr>
<tr>
<td>Metal</td>
<td>0.920</td>
<td>0.846</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.945</td>
<td>0.590</td>
</tr>
<tr>
<td>Plastic and rubber</td>
<td>0.942</td>
<td>0.989</td>
</tr>
<tr>
<td>Mechanic Components</td>
<td>0.905</td>
<td>0.730</td>
</tr>
<tr>
<td>Electronic</td>
<td>0.967</td>
<td>1.016</td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro</td>
<td>0.954</td>
<td>0.756</td>
</tr>
<tr>
<td>Small</td>
<td>0.899</td>
<td>0.773</td>
</tr>
<tr>
<td>Medium</td>
<td>0.927</td>
<td>0.831</td>
</tr>
<tr>
<td>Medium Large</td>
<td>0.897</td>
<td>0.827</td>
</tr>
<tr>
<td>Large</td>
<td>0.892</td>
<td>0.824</td>
</tr>
<tr>
<td>Make or buy strategy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deverticalized</td>
<td>0.922</td>
<td>0.887</td>
</tr>
<tr>
<td>Deverticalized</td>
<td>0.895</td>
<td>0.788</td>
</tr>
<tr>
<td>Integrated</td>
<td>0.905</td>
<td>0.750</td>
</tr>
<tr>
<td>Highly Integrated</td>
<td>0.957</td>
<td>0.729</td>
</tr>
</tbody>
</table>

Therefore, on average, those firms can show TFP growth only via own technical progress with minor contribution of efficiency recovery, that during the recent crisis has been negative, with a relative increase of the distance to the new frontier. Highly integrated businesses, more disadvantaged in terms of pure technical efficiency, show the better performance in term of TFP direct outcome of the larger TECH contribution (7%) that confirms the group is characterized by the higher heterogeneity. Also for the TFP growth, vertical strategy is not neutral and this is also confirmed by the Kruskal-Wallis tests highlighting statistically significant differences across the 4 groups.

Concerning size, the situation appears very different from section 5.1, where the empirical evidence is against micro and small size. Indeed, considering the productivity changes, the relation with size is not clear: micro firms show the smallest decrease, mainly driven by strong technical progresses. Small firms are in general farer from the frontier than other kind of firms, and then in terms of growth, the potential of increasing TFP by recovering in comparison to the best firms are higher. This is equivalent to say that the production frontier has shifted upwards more intensively for micro and small firms than for other firms, implying the existence of a minority of very efficient SMEs driving progress: the average rates of yearly technical progress are the highest: + 5.9% for micro and + 3.9% for the small
ones. However, even if some SMEs are able to find new opportunities thanks to imitation of best practice firms, many firms cannot do the same and the efficiency drops at a remarkable rate of 6% for each year. The ability of applying best practice techniques of micro and small firms is similar, but the lower frontier shift of the second group determines a lower TFP performance.

Large firms are in general closed to the frontier, as showed in table 5, limiting, by construction the role of technical progress in sustaining TFP changes, as highlighted in table 6. Large firms were close to the frontier during 2007 and, on average, they can only boost productivity by self-shifting the frontier upwards: being on the frontier reduce possibility of enhancing productivity by recovering efficiency because efficiency is already full. In case of large firms, the most efficient group in the static analysis, the only way of increasing TFP is by producing innovation and, consequently, taking advantage of technical progress: in fact it play a minor role in table 6. The outcome of the crisis, limiting capacity utilization through a decreasing demand, is an increasing distance from the best practice frontier that exceed the advantages, in TFP term, of the limited technical progress. Also in the case of size, the Kruskal-Wallis tests reject the null hypothesis of negligible differences across size classes.

6 Conclusions and final remarks

This study has analyzed a large sample of Italian firms involved in different phases of the automotive value chain, strongly influenced by the recent international crisis. The sample has been obtained by the merge of different data source and database previously used in different studies: the result is one of the most complete set of firms operating in the Italian automotive sector. We have considered the last financial data before the crisis (2007) and one of the last available data (2011) to have a clear picture of its impact in the medium term. We have computed the productivity performance of each firm in each year using two set of instruments strictly linked one to each other. In a first static analysis we compute technical efficiency indicators by applying the DEA framework in its most modern version, enriched by the bootstrap tool, to obtain more robust and reliable results, as suggested by Simar and Wilson (1998). Moreover, the work is completed by the computation of total factor productivity changes for the period 2007-2011 verifying, in most of the cases, a contraction in the productivity levels. The results are not encouraging, but they are somehow expected: the crisis has reduced the production volumes with an under-utilization of fixed factors that can be quantified through the TFP contractions and a generalized reduction of average efficiency level of firms.

One main purpose, however, is the attempt to use DEA in a context of value chain analysis, and some
results support the effort of highlighting characters of roles defined through the activities of the firms. In doing so, we have presented an example of how industrial economics could be oriented to explore points of strength and weakness in self-organizing systems, which are characterized by firm heterogeneity.

Following that line of research, we have confirmed that productivity analysis shows sound differences between and within the main activity pertaining to the automotive value chain. Moreover, our contribution also explores other important aspect of firms such as the heterogeneity in term of vertical integration strategies and size, confirming the main indication from literature on industrial dynamics. Firms which concentrate efforts on their own core business appear more efficient in combining input to obtain outputs, and the same emerges for large firms that on average adopt technologies closer to the best practice frontier. That evidence is not the simple result of a stochastic distribution of managerial errors, but an unavoidable consequence of different roles, histories and learning capabilities, according to the interpretation proposed by Dosi et al. (2012).

Detecting these differences could be useful also for an industrial policy perspective. For example, we have found that activities like Metals and Mechanic Components, more linked to traditional technologies, show the lower average efficiency scores (i.e. higher heterogeneity in terms of technical efficiency performances), and these are undoubtedly areas of interest. At the end of the selection mechanism induced by the crisis, the results will probably be the coexistence of a small number top-performer firms and a wide number of low-performers, with a distance between the two groups that has increased dramatically. Future industrial policies have to partially rethink their role and find new instruments to reduce the distance between the two groups and re-balance the production system. In fact, we have shown that some firms were able to react better or suffer less than others during a downturn period that has been exacerbated by the long run FIAT delocalization strategy, structurally reducing internal demand.

The differences between the two identified group of firms can be the core of future recovery process: strengthening the heterogeneity is a positive character of the economic system, even though the final and relevant question will be how to involve other firms in a new and general TFP growth path.

A first indication can arise from the investigation on make or buy decision that appears to deeply influence efficiency performances and TFP changes. We have created four groups of firms characterized by four different strategies in term of vertical integration and we find that the vertical structure has a clear effect on technical efficiency: the higher the level of vertical integration the higher the level of inefficiency. The results are stable over time: those firms which
decide to focus on their own competences show better performances in term of efficiency also
during the and firms closer to the best practice frontier remain more concentrated in the high
deverticalized group.

Finally, investigating the issue of firm size we obtain two main indications. On one hand, we have
found evidence supporting the higher technical efficiency of large firms, due to the impact of scale
economies that make them, on average, closer to the best practice frontier during the analyzed period.
However, from the other hand, during the crisis, large firms seem to suffer more than medium firms,
probably for their lower flexibility, leading them farther away from the 2011 frontier. In terms of TFP
growth more efficient firms in the static analysis are disadvantaged because being near the frontier
reduces the possibility of taking advantage of the imitation effect, the so-called “catching up” effect.
Firms near the frontier, like also disintegrated firms, cannot apply new solutions created in the
proximity, because no imitation effects are possible. They can only sustain productivity through
their own innovations: this removes an important source of TFP growth lowering the Malmquist
indexes, with results in contrast with the outcome of static DEA model. Nevertheless, focusing the
attention on the two components of TFP change, technical progress and efficiency recovery, the
evidence of and increasing heterogeneity among firms is confirmed.
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