Are outsourcers and non-outsourcers really different? Flexibility and advanced manufacturing technology

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Abstract

We study the differences between outsourcers (i.e. firms which outsource production) and non-outsourcers (i.e. vertically integrated firms), in order to understand the association between production networks and technical/strategic change. We use chi-square tests, t-tests and multivariate tests to analyse a sample of 1,031 industrial plants, representative of Spanish national industry. Hypotheses are tested for three subsets of companies, classified by the R&D intensity of the industry in which they operate. The data show that outsourcers and non-outsourcers do not differ with regard to some of the most important determinants of new technology adoption, such as company size; however, outsourcers are more likely to utilise advanced manufacturing technology and to engage in flexible production. Vertically integrated firms, by contrast, are more likely to employ traditional manufacturing equipment and to employ a strategy based on mass production. Nevertheless, the implementation of flexible production does not *per se* lead to AMT adoption. Although industrial change is significantly linked to production networks, the data also provide some preliminary evidence of the limits of such change.

Key words: Outsourcing, corporate governance, flexible production, advanced manufacturing technology.

1. Introduction

During the last two decades, production networks have acquired increasing importance in the industry of developed countries and are currently spreading to developing countries, principally via offshoring. Once confined to a few sectors, locations and specific types of companies (i.e. small and medium-sized enterprises), outsourcing arrangements have become widespread, involving companies of different sizes in a variety of manufacturing industries and locations (EUROSTAT, 1998) (European-Commission, 1997; Holl, 2004; Kakabadse & Kakabadse, 2002).

Although there exists *"a general widespread pro-network bias"* (Grandori, 1999, p. 2), policy decisions and expectations with regard to outsourcing are often insufficiently informed. Systematic research into the differences between companies engaged in production networks and vertically integrated companies (i.e. outsourcers and non-outsourcers) remains scarce. Even the advantages outsourcers allegedly enjoy over non-outsourcers have often been inadequately understood. An important issue is whether companies which outsource production, owing to their links with other firms, may be vehicles for the diffusion of new technology and the modernisation of their sector; it also remains unclear whether outsourcers are more likely than non-outsourcers to adopt advanced technology. One reason why companies outsource production appears to be, after all, to avoid investment in expensive equipment (Berggren & Bengtsson, 2004; De Propris, 2001). So far, the debate on this subject has left a practical question unanswered: is outsourcing superior to other forms of corporate governance in promoting the diffusion of new manufacturing technology in their sector. Furthermore, flexibility, a trait the literature often associates with production networks, has rarely been studied in its general dimension. The alleged shift towards flexible production has largely been analysed within local production systems (Becattini 2002; De Propris, 2001; Paniccia, 1998; Storper & Harrison, 1991). Given the increasing popularity of offshoring and extra-regional production networks (Hagedoorn, 1994; Holl & Rama, 2009; Mol, 2004; Mol, van Tulder, & Beije, 2005; Sako, 2005; Sturgeon, 2002), it would be useful to understand more clearly whether all types of networks (not only local

ones) are associated with the new strategy of flexibility. Finally, the dimension of change associated with production networks is imprecisely known and, unsurprisingly, researchers' interpretations differ. Some authors support the concept of the heterogeneity of organisational forms, which implies the coexistence of different forms (Morroni, 2009), while others observe a radical shift in the industrial paradigm (Acemoglu, Ahion, Griffith, & Zilibotti, 2007; Milgrom & Roberts, 1990; Sturgeon, 2002). In short, the relationship between production networks and industrial change is only partially understood.

This is partly due to a lack of empirical analyses. Firstly, while the empirical literature in this field has provided important insights and analyses, it has been mainly concerned with case studies, rarely offering systematic evidence. There is still a considerable dearth of statistical analyses to complement such research and provide a broader picture of the phenomenon. Secondly, most of the models of industries which rely on external economies have been built on examples taken from Japan, Italy and Germany and have concentrated on specific sectors, such as automobiles, within these countries (Sturgeon, 2002). Analyses of national industrial organisations (and sectors) other than those traditionally studied by previous researchers may help to draw a more accurate picture of the new paradigm for industrial organisation because, as Whittington et al. note (Whittington, Pettigrew, Peck, Fenton, & Conyon, 1999), systemic change varies not only across countries but also across industries.

We hypothesise that outsourcing arrangements cohere, at the industrial plant level, with i) the implementation of a flexibility strategy and ii) the employment of AMT, or advanced manufacturing technology (see definitions below). Our hypotheses are open to empirical confirmation or rejection by the data collected in the course of our research. We analyse data taken from a plant-level survey of Spanish industrial firms, conducted in 2003. The total sample included 1,031 companies, all of which had 50 or more employees. Given their size, sector and geographic location, our sample is representative of Spanish industrial companies with over 50 employees. Following Italy and Portugal, Spain hosts the largest subcontracting industry in the EU-15 (EUROSTAT, 1998).

The main contributions of our paper are as follows. For the first time (to our knowledge), strategic and technological change associated with companies' involvement in outsourcing arrangements is systematically tested using a database representative of an entire national industry. Another contribution of our study is that our hypotheses are tested for three subsets of companies, grouped according to the R&D intensity of their respective industries (26 manufacturing industries in total). Firms' technological conditions (Pavitt, 1984; von Tunzelmann & Acha, 2005) and their propensity to outsource (Díaz-Mora, 2005; European-Commission, 1997) may differ between high-tech and low-tech industries; moreover, the need for flexibility appears to vary from one sector to another (Morroni, 1991; von Tunzelmann, 1995).

Sections 2 and 3 deal with the theoretical background which informs our research; they also present our hypotheses. Section 4 describes the data and variables used in the empirical analysis. Section 5 tests for differences between outsourcers and non-outsourcers, while Section 6 presents our conclusions.

2. Flexibility and a logic of organisational forms

Our point of departure is, in line with previous research, the idea of an underlying rationale of organisational forms. The field of organisation studies has traditionally viewed firms as clusters of features and attributes, usually associated in a coherent form (Fiss, 2007; Grandori & Furnari, 2009; Teece & Pisano, 1994).

Research into outsourcing stems from various roots, such as organisational theory and network theory (Ritter & Gemünden, 2003). Based on the available literature, and following the definition of two key terms, a hypothesis regarding outsourcing and flexibility is constructed.

2.1 Key terms

Production outsourcing (subcontracting) is an arrangement in which a company, the outsourcer (client or contractor), requests from another independent firm (supplier or subcontractor) the supply of an input or of parts and components; these must be manufactured according to the outsourcer's specifications. The outsourcer often provides the supplier (subcontractor) with

product specifications, materials and machines, technical and financial assistance and quality control (Larsson, 1999).

AMT consists of computer-based technologies for manufacturing and communications, such as Computer Assisted Design/Computer Assisted Engineering (CAD/CAE). For descriptions of some important elements of AMT, see Appendix 1.

2.2 Flexible production

Von Tunzelmann (1995, p.263) states that *"flexibility comes from the alleged ability to redesign products very rapidly in response to perceived market forces"* [1].

According to the literature, firms participating in production outsourcing often employ a strategy based on the flexibility of production. As early as the 1960s, Burns and Stakler (1961) claimed that changing demand had created the need for an organic organisation of the firm, one stressing innovation and production flexibility. The 1970s and 1980s witnessed the widespread customisation of production i.e. the process of producing small batches of items custom designed to suit each particular client (Piore and Sabel, 1984). Through outsourcing, some authors argue, firms can take advantage of consumer heterogeneity (Sturgeon, 2002). The literature explains the association between outsourcing and flexible production by the advantages of partners' specialisation. This type of "modular production system" often requires the establishment of networks of producers who specialise in different parts and components (Langlois & Robertson, 1992, p.27). According to Cohendet and Llerena (2009), systems based on product variety cohere with production networks because this form of organisation is well suited to promote the differentiation of skills; by contrast, they argue, in mass production systems specialisation takes place mainly within the company.

Empirical studies tend to consider outsourcing as a popular strategy firms employ to achieve product differentiation (Kakabadse & Kakabadse, 2002; Pittaway, Robertson, Munir, Denyer, & Neely, 2004). Some studies associate the mass production of standardised goods for large homogeneous markets with vertically integrated firms, and flexible and small batch production with companies engaged in outsourcing arrangements (Bessant & Haywood, 1988;

De Propris, 2001; Larsson, 1999). As stated previously, these theses have mainly been tested for local production networks.

We propose, consequently:

H1. Outsourcers, compared with a similar sample of Non-Outsourcers, are more inclined to produce customised items and small product batches.

3. Participation in production networks and AMT

This section discusses studies of the association between modern outsourcing practices and the use of AMT at the industrial plant level. While some authors see a positive association between the two, others suggest the relationship is negative. Network theory and the industrial district literature often consider outsourcing arrangements to be a solution to firms' problems, such as resource scarcity (see, for instance, Berggren & Bengtsson, 2004; Ghisi & Martinelli, 2006; Havnes & Senneseth, 2001; Hertz, 1992); insufficient capital is one such shortage. Via outsourcing, runs the argument, companies are able to quickly increase their output without incurring additional capital investment. Consequently, outsourcers may have lower manufacturing technology requirements than non-outsourcers. Moreover, some studies show that suppliers, rather than outsourcers (contractors), play a leading technological role in various specific networks (Sturgeon, 2002), an arrangement which may reduce outsourcers' needs for manufacturing technology.

By contrast, other academics believe that information and communication technology (ICT), an important element of AMT, is producing a shift from the old integrated firm towards production outsourcing (see, for instance, Acemoglu et al., 2007). Milgrom and Roberts (1990) argue that adopters of AMT, a technology which enables manufacturing plants to switch cheaply from one task to another and produce small batches of customised items, tend to interrelate closely with their suppliers.

However, previous research provides inconclusive empirical evidence concerning the association between production networks and company

employment of AMT. Milgrom and Roberts (1990) offer a convincing account of why outsourcers employ AMT, but do not supply empirical evidence to support their theory. Tests concerning the combination of outsourcing with a detailed list of different kinds of AMT are scarce or non-existent. As Bocquet et al. (2007) note, most previous tests of complementarities have confined such analysis to computers and automation tools. Others, by contrast, focus exclusively upon ICT and only find associations in certain cases. A study based on a sample of large and medium-sized Western European firms finds outsourcing is moderately associated with the extensive use of ICT only in high-performing companies (Whittington et al., 1999). Following the analysis of a sample of 129 French firms, Bocquet et al. (2007) find that only some ICT (not all) complement a firm's tendency to interact with suppliers and customers; again, companies combine such strategies in specific cases i.e. when quality is an important issue. It is difficult to determine from previous research whether outsourcing is associated with AMT in general. Whatever the case, the questions arising indicate the need to investigate whether outsourcing is associated with the use of a variety of specific technologies (ICT, design technology, etc.).

Consequently, we test the following hypothesis:

H2 Outsourcers, compared with a similar sample of non-outsourcers, are more likely to utilise advanced manufacturing technology in the industrial plant.

We test for association rather than for causality between these factors. The principal body of organisation theory assumes that decisions concerning organisational form and technology are *simultaneously* adopted by the firm (Madhok, 1996; Milgrom & Roberts, 1990; Williamson, 1991). In line with other empirical studies in the field (Whittington et al., 1999), we adhere to this theory, which implies association rather than causality between company adoption of AMT and engagement in production networks.

4. Empirical data

4.1. The survey

The data employed in the following analysis were obtained from a plant-level survey targeting firms in the Spanish industry and conducted in 2003. All the companies had 50 or more employees[2]. In order to establish the dimension of the population of plants in terms of sector, region and size, we used the information contained in the Central Directory of Enterprises (Directorio Central de Empresas or DIRCE), compiled by the National Institute of Statistics. To select the sample, the regional and sectoral distribution of plants indicated by the DIRCE was taken into account. Here, regions are the 17 Spanish Autonomous Communities. Sectors were defined according to the CNAE classification (National Classification of Economic Activities), similar to the European NACE rev1. We selected companies for analysis from the Dun & Bradstreet Spain list. As stated, given their size, sector and geographic location, the sampled firms are statistically representative of firms with over 50 employees in the Spanish industry. For a confidence level of 95.5%, the sampling error is ± 2.8%. Our sample includes the Spanish affiliates of important multinational enterprises, such as Danone, General Electric, Pepsico, Renault, Siemens, etc., and well-known Spanish companies such as Lladró, Mondragón and others. A pre-test of the questionnaire was conducted and all the principal problems encountered (e.g. poor understanding of some questions) were addressed before the fieldwork was commenced. At the company level, in most cases we interviewed Directors of Production, each personal interview lasting approximately one hour. The survey does not suffer from significant item non-response.

We asked the sampled firms in which sector they operated, according to the CNAE classification. We subsequently classified the 26 manufacturing industries in which these companies operate into three groups, according to the R&D intensity (average R&D/turnover) of the industry. In doing so we used the OECD classification, which establishes the following cutoff points for average R&D/turnover: 0.9%; 3%; and 5%. For instance, in industries classified as having low R&D intensity, their average R&D/turnover is below 0.9%. We consequently divided the sample into three subsets, namely firms operating in: 1) Low R&D intensity industries[3]; 2) Medium-Low R&D intensity industries[4]; and 3) Medium-High[5] and High[6] R&D intensity industries. As stated earlier,

hypotheses were tested using data for the full sample of companies and for each of the three subsets.

The variables (see definitions in Appendix 2) were selected on the basis of the discussion in Section 3. The ORGANISATION variable has two categories, outsourcers (i.e. firms which have outsourced some production in the last three years) and non-outsourcers.

Firstly, we study differences between outsourcers and non-outsourcers with regard to i) flexibility strategy and ii) the employment of AMT, by analysing pairwise complementarities. Secondly, we examine the interaction between a flexibility strategy and the utilisation of AMT in outsourcers and non-outsourcers.

4.2. Characteristics of the sample

Of the firms sampled, 41.8% operate in Low R&D intensity industries, 31.0% in Medium-low intensity industries and 27.2% in Medium-high and High intensity industries. outsourcers account for 64.6% of the sampled firms and non-outsourcers for 34.9%. The percentage of outsourcers is somewhat high but is in accordance with previous studies of outsourcing in various Spanish industries (Díaz-Mora, 2005; Suarez-Villa & Rama, 1996) and with EUROSTAT (1998). Perspective for this figure is also provided by a study of a large sample of French companies with more than 50 employees, which found that only half of them outsourced some production in the 1990s (Greenan & Mairesse, 2001). Among the outsourcers sampled, 81.8% of companies outsource less than 25% of production and 18.2%, which we call heavy outsourcers, outsource 25% or more. Some of the tests are performed both for outsourcers (all sampled companies which outsource production) and, more specifically, for heavy outsourcers.

In our sample, differences between outsourcers and non-outsourcers concerning size, ownership and principal market characteristics are not statistically significant (Table 1). This is an important finding because, according to theory (Hall, 2005; Karshenas & Stoneman, 1995), such factors may influence company decisions regarding the adoption of new technology. The

result suggests that these key variables do not account for possible differences between outsourcers and non-outsourcers concerning technology adoption.

Insert Table 1 here

5. Results and discussion

5.1. Outsourcing and production flexibility

This subsection presents the results of the statistical analyses performed to test H1 (Outsourcers are more likely to produce customised items and small product batches).

Flexibility involves the customisation of production, defined as the degree to which a product is manufactured in accordance with a customer's specifications (Cabello Medina, Carmona Lavado, & Valle Cabrera, 2005). The PRODUCTION variable proxies a strategy based on production flexibility (see definition in Appendix 2). The companies surveyed were asked to indicate which of the following statements best described their activities: the manufacture of 1) small batches of a great variety of products and custom-made products; 2) large batches of technically homogeneous products and products in a continuous flow system. The first question approximates flexible production and the second, mass production. A chi-square test demonstrates a significant association between organisation type and the probability of engaging in flexible production (χ^2 (1) = 23.243, $p < 0.001$). As Table 2 shows, outsourcers tend to manufacture products custom-made or in small batches (52.7% of outsourcers). Non-Outsourcers, by contrast, are more likely to produce large batches (63.3% of such companies). The preference of outsourcers for flexible production is confirmed when we examine, more specifically, firms which outsource more than 25% of production (χ^2 (1) = 30.441, $p < 0.001$) (Table 2). It can be seen that the results are robust to changes in the sets of industries, classified by R&D intensity. Employing the odds ratio, we find that the probability of companies engaging principally in flexible production is 2.0 times higher for utsourcers and 3.4 times higher for

heavy outsourcers. This finding is confirmed for each of the three subsets of firms.

We conclude that *H1* is proven: Outsourcers are more likely than non-outsourcers to engage in flexible production. Our findings show that all types of production networks (and not only regional ones) are likely to cohere with such a strategy. This is an important result, given the increasing popularity of offshoring and extra-regional production networks; it suggests that modern production networks (and not only local ones) are likely to cohere with companies' flexibility strategies.

Insert Table 2 here

The empirical evidence certainly suggests that production networks are substantially associated with new corporate strategies related to the customisation of production and fragmented markets. However, as occurs in other studies, this is merely a probabilistic statement and a deeper understanding of the true dimensions of this relationship is required. As Table 2 shows, coincidence between the organisation model (outsourcer versus non-outsourcer) and the strategy model (flexible production versus mass production) is not complete. 47.3% of outsourcers (and 33.3% of heavy outsourcers) are principally committed to mass production and, conversely, 36.8% of non-outsourcers are mainly dedicated to flexible production. Furthermore, despite some authors claiming in the 1990s that increased competition would made vertical structures anachronistic and lead to flexibility and inter-firm collaboration (Whittington et al., 1999), our results show, approximately a decade later, that vertically integrated firms manufacturing standardised goods and outsourcers providing customised items still coexist in every sector of Spanish industry, notwithstanding their degree of R&D intensity. Our results support the view (Morroni, 2009) that mass production and flexible production may coexist within an industry, as these different forms of manufacturing probably cater to different customers' needs.

Insert Table 3 here

5.2. Equipment age

As noted in Section 4.2., in our sample outsourcers and non-outsourcers do not differ with regard to their size and other relevant characteristics which may influence technology adoption. To gain further insight into the possible combination of outsourcing arrangements and AMT adoption, we also analyse the age of the equipment utilised by the firms sampled. The age of equipment is an indicator of technological innovation (Grupp, 1998b) and may also influence company decisions concerning the adoption of technology (Karshenas & Stoneman, 1995).

We now test for differences regarding the average age of outsourcers' and non-outsourcers' manufacturing equipment, both standard and AMT (see the definition of AGE in Appendix 2). A multivariate test (Pillai's trace test) demonstrates that the average age of the respective equipment used by outsourcers and non-outsourcers is similar ($F = 0.084$; $p = 0.969$). When we take into account the type of industry in which companies operate, the similarity between outsourcers and non-outsourcers in this respect is confirmed ($F = 0.573$; $p = 0.752$).

Our results provide a counterpoint to earlier research. According to a study of American electronics firms, companies which outsource production may be able to increase volume without installing additional in-house equipment, since suppliers offer external economies of scope i.e. at least part of manufacturing services and manufacturing technology. In other words, clients no longer exclusively bear the burden of large-scale investment in fixed capital (Sturgeon, 2002), and it may be concluded that, in the US electronics industry he studies, outsourcers have less need for manufacturing assets than integrated firms. Our data suggest, by contrast, that outsourcers and non-outsourcers have similar equipment requirements in each of the Spanish industrial sets, at least with regard to age of the equipment. The cause of this discrepancy with Sturgeon's findings may lie in the different roles played by suppliers (subcontractors) in different national productive organisations. For example, Brusco (1999) shows that in Italian manufacturing districts it is usually

the contractor (and not the supplier) who invests in machinery, especially high-value machinery, and lends it to the supplier when needed.

To explore further the role of subcontractors in our sample, we analyse the reasons for outsourcing. Outsourcers were asked whether the lack of specialised machinery was a motive for outsourcing production, and companies responded according to a 1-5 Likert scale (1= not important motive and 5 =very important). Only 17.8% of firms (and 18.4% of those operating in Medium-high and High R&D intensity industries) rated such a motive as "very important"[7]. This result further suggests that in Spanish manufacturing industry it is contractors rather than suppliers who are more likely to invest in specialised machinery, as in the Italian case study. Once more, our results confirm the need to examine a variety of national models of industrial organisation in order to draw an accurate picture of the new industrial paradigm.

5.3. Advanced Manufacturing Technology

The literature offers two principal explanations of why firms presumably combine participation in production networks and the utilisation of AMT. Firstly, ICT facilitates inter-firm linkages by reducing coordination costs. Rapid and reliable communication on a day-to-day basis is crucial to ensure continuous coordination between outsourcers and their suppliers (Larsson, 1999). Secondly, advanced manufacturing and design technology (another type of AMT) may facilitate variety-based production by reducing design and manufacturing costs. As previously demonstrated, outsourcers are likely to implement flexible production in their industrial plants.

To test H2 (i.e. Outsourcers are more likely to utilise AMT), we compare the average number of technologies used by outsourcers and non-outsourcers and subsequently analyse the differences between them concerning the use of combined AMT and of individual technologies. Some authors (Milgrom & Roberts, 1990) argue that the various types of AMT provide better results if used together instead of in isolation. Therefore, we start by investigating how many such technologies are utilised by the average outsourcer and the average mon-outsourcer. Definitions of the variables used in the analysis are to be found under the heading "Advanced Manufacturing Technology", which includes three

sub-groups: i) design and engineering technology, ii) manufacturing technology and iii) communications and control technology (see Appendix 2). As stated, some of their technical characteristics are briefly described in Appendix 1. Outsourcers, compared to non-outsourcers, employ a greater variety of AMT, a result confirmed for each of the three subsets of companies and significant at the 1% level (Table 3). Technological change associated with production networks is further confirmed when we examine heavy outsourcers (Table 3), who on average use four different technologies, while non-outsourcers use only 2.8 (significant at 1%). Moreover, heavy outsourcers i.e. contractors which could in theory rely strongly on their suppliers for technology, since they outsource 25% or more of production, actually invested in the broadest range of R&D intensive equipment; this result is confirmed for companies in every group of Spanish industries. To summarise, these data further refute the thesis that companies use outsourcing to reduce their investment requirements. If investment in R&D intensive equipment is an indicator of the technical resources available to companies, as some authors hold (Grupp, 1998a), our data suggest that outsourcers possess technological assets similar to or even larger than non-outsourcers.

Insert Table 4 here

The surveyed companies were asked eight specific questions regarding AMT usage (see Appendix 2). We defined such multiple response variables as a multiple response set[8], which we treated in exactly the same fashion as a normal categorical variable ($ATM). We then studied the association between $ATM and ORGANISATION. A chi-square test showed a significant association between both variables ($\chi^2(8) = 142.906$, $p < 0.05$), and thus outsourcers are more likely to adopt a combination of different AMT. We may conclude, following Milgrom and Roberts (1990), that outsourcers obtain better results from their combined investments, since different types of AMT work better when used together.

However, each type of AMT must be carefully analysed as a separate variable. Firms may adopt only some of the AMT in isolation (and not the combined form defined by $AMT). Secondly, different types of ICT may have

different impacts upon communications costs (Reinstaller & Windrum, 2009), and consequently upon companies' participation in production networks. We hypothesize that outsourcers are more likely than non-outsourcers to use each of the eight different types of machines studied here (see definitions in Appendix 2). In what follows, we test for differences between outsourcers and non-outsourcers concerning the plant-level utilisation of each type of technology[9]. As Appendix 1 shows, these all are important elements of AMT.

We start by testing for association between ORGANISATION and three variables describing design and engineering technologies used by industrial plants (CAD/CAE, CAD/CAM and CAD/Purchases) (see Appendix 2). A chi-square test shows that differences between outsourcers and non-outsourcers are statistically significant, a result corroborated by the analysis of each of the three company subsets (see Appendix 3). Outsourcers are more likely to utilise CAD/CAE, CAD/CAM and CAD/Purchase (each test significant at 1%). This result is coherent with the strategic importance such companies assign to product design.

We now test for association between ORGANISATION and three variables describing manufacturing technology. Outsourcers are more inclined to use NC/CNC (significant at 1%), FMC/FMS (significant at 1%) and lasers (significant at 10%); positive associations are corroborated for two of the three company subsets (see Appendix 3). This finding confirms the thesis of Milgrom and Roberts (1990), namely that the employment of versatile manufacturing technology is associated with company maintenance of strong relationships with suppliers.

The next test is for differences between the two types of organisations with regard to the use of communication and control technology. Outsourcers are more likely to employ LAN and LAN FACTORY (each test is significant at 1%); positive associations are confirmed for each of the three subsets of companies, classified by R&D intensity (see Appendix 3). This supports previous findings regarding the association between ICT adoption and company involvement in outsourcing networks (Acemoglu et al., 2007).

To summarise, study of the investment made by the sampled firms in various types of advanced machines always reveals statistically significant differences between outsourcers and non-outsourcers. The former are always

more likely to have invested in AMT, because outsourcing tends to cohere with each of the three kinds of AMT studied here: design and engineering technology, manufacturing technology and communications and control technology.

However, the size effect varies between technologies. For example, the odds of an outsourcer using FNC/FMS are 2.0 times higher than for a non-outsourcer, and this ratio climbs to 2.5 for outsourcers operating in Medium-High and High R&D intensity industries. When we focus on other technologies, however, the association with ORGANISATION is weaker, although statistically significant[10]. Our result is coherent with Bocquet et al. (2007); when testing for complementarities between modern organisational practices and (information) technologies is performed in a comprehensive fashion, they argue, the results are less straightforward than those provided by theoretical models, such as that of Milgrom and Roberts (1990).

Our finding with regard to AMT does not imply that non-outsourcers employ obsolete manufacturing equipment (see Subsection 5.2); traditional equipment is not necessarily "old" equipment. The technologies used by each type of organisation differ because they serve different purposes, not because they have different levels of obsolescence. AMT is not an evolutionary form of standard technology.

To summarise, H2 (i.e. Outsourcers are more likely than non-outsourcers to utilise AMT) is confirmed by the statistical analyses. The result disproves the argument that firms necessarily reduce their investment requirements by outsourcing production.

5.4. Interactions

As stated earlier, previous research has argued that AMT may facilitate variety-based production by reducing design and manufacturing costs at the plant level. This view suggests that the reasons why outsourcers adopt AMT are to be sought in their flexibility strategy. The question left unanswered, however, is whether it is the type of strategy (rather than the type of organisation) which is associated with company adoption of AMT.

We turn our attention now to the interaction between PRODUCTION and $AMT, but we perform the test separately for outsourcers and non-outsourcers. As Table 2 shows, a certain proportion of non-outsourcers also tend to follow a flexibility strategy; the test allows us to learn whether they are likely to use AMT. A chi-square test and a Bonferroni test show that $AMT (the multi-response set described previously) and PRODUCTION are associated in the case of outsourcers (χ^2 (3) = 18.093 3.621; $p < 0.05$) but not for non-outsourcers (χ^2 (3) = 3.621; $p = 0.891$).

The results are similar when we confine the analysis to manufacturing technology i.e. NC/CNC, FMC/FMS and lasers ($\chi^2(3)= 10.216$, $p = 0.01$ and χ^2 (3) = 3.410, $p = 0.333$ for outsourcers and non-outsourcers, respectively). The implementation of a flexibility strategy is associated with the use of AMT only in outsourcers. Although this finding does not allow us to draw any firm theoretical conclusions, it suggests that the implementation of flexible production does not *per se* lead to the adoption of AMT; the type of organisation appears to play a key role in this decision.

6. Conclusions

We analysed the association between technological and strategic change and production networks; our sample of 1,031 companies, both outsourcers and non-outsourcers, is statistically representative of the Spanish manufacturing firms which have at least 50 employees.

Production networks are associated with flexible production in every group of Spanish industries, from the most R&D intensive to the least. Irrespective of the industry, production networks are also associated with the adoption of Advanced Manufacturing Technology at the industrial plant level. The empirical evidence shows that while outsourcers and non-outsourcers do not differ with regard to some of the most important determinants of the adoption of new technology, such as size, outsourcers are more likely to utilise AMT. Vertically integrated firms, by contrast, are more likely to employ traditional manufacturing equipment and a strategy based on mass production.

In our sample, the implementation of flexible production does not *per se* lead to AMT adoption. This finding confirms the view of Morroni (1991), namely

that flexible production may “arise from the way elements of production are organized, regardless of the technology being used”; in other words, it may be organisational form rather than flexible production which creates favourable conditions for AMT adoption. If a vertically integrated firm is committed to flexible production, it is less likely to adopt AMT. Although we cannot draw firm theoretical conclusions from this finding, company decisions concerning strategy, technology and organisation might be merely steps in a longer process. Our data do not, however, permit us to test this hypothesis.

Outsourcers may occasionally be able to utilise the temporary excess capacity of their subcontractors (Ring, 1999). However, our data do not support the thesis that, by forming networks, interconnected firms can access some resources without paying their full acquisition cost, as sometimes suggested by network theory, the literature on industrial districts (see, for instance, Berggren & Bengtsson, 2004; Ghisi & Martinelli, 2006; Havnes & Senneseth, 2001; Hertz, 1992) and some interpretations of the resource-based view of the firm (Lavie, 2006). In Spanish manufacturing industry, outsourcers’ investments tend to be similar to those of non-outsourcers with regard to the age of equipment while their need to invest in varied technology is higher.

To summarise, in every type of industry outsourcers appear to employ a form of corporate governance especially efficient for the diffusion of new technology. Industries where subcontractors play a leading technological role within networks (Sturgeon, 2002) may be an exception in this respect; no noticeable evidence of such an arrangement was found in Spanish manufacturing industry, however, even in Medium-High and High R&D intensive industries.

Although the association between industrial change and production networks is substantial, our data also provide some preliminary evidence of the limits of such change. Outsourcers and integrated firms coexist in every type of Spanish industry; moreover, a proportion of outsourcers are inclined towards mass production and a proportion of non-outsourcers are inclined towards flexible production. The generalised shift towards new forms of organisation predicted by some authors (Acemoglu et al., 2007; Sturgeon, 2002) has not yet occurred in Spanish manufacturing industry. Instead, our data support the thesis that organisational forms are heterogeneous, which implies the

coexistence of different forms (Morroni, 2009). On the other hand, the association between company participation in outsourcing arrangements and the usage of some specific AMT is, although statistically representative, only moderate.

Our research, nevertheless, focuses on a single country and needs to be supplemented by other statistically representative studies of national manufacturing industries.

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Table 1. Sample characteristics, by type of organisation

Variables (1)	**Outsourcers**	**Non-Outsourcers**
SIZE (2) Average number of employees	162	140
OWNERSHIP (3) % of subsidiaries and joint-vent.	24.5	24.2
MARKET (2)	3.77	3.71

Notes: (1) Definitions in Appendix 2.
(2) Based on the mean comparison t-tests. Differences are not statistically significant.
(3) Based on cross-tabulations using Pearson's chi-square test. Differences are not statistically significant.

Table 2

Percentage (%) of firms producing small batches and customised items, by type of industry (1) (2)

Sample and subsamples	All Outsourcers	Outsourcers ≥ 25% (3)	Non-Outsourcers
Total sample	52.7 *	66.4 *	36.8
Low R&D intensity ind.	54.8 *	66.0 *	38.5
Medium-low R&D intensity ind.	47.1 **	60.0 **	32.4
Medium-high and High R&D intensity ind.	56.0 *	70.0 *	38.6

Source: Authors' calculations, based on survey data.
Notes: (1) Classification of industries by R&D intensity in the text.
(2) For definitions of variables, see Appendix 2 (PRODUCTION).
(3) Outsourcers which outsourced ≥ 25% of production in the last year (heavy outsourcers)
* Significant at 1%; ** significant at 5%
Results of chi-square tests are based on comparisons of all outsourcers and non-outsources, and comparisons of outsourcers ≥ 25% (heavy outsourcers) and non-outsourcers.

Table 3. Average number of AMT employed by firms, by type of industry (1)

Sample and subsamples	All Outsourcers	Outsourcers ≥ 25% (3)	Non-Outsourcers
Total sample	3.8904 * (1.90172)	4.0171 * (1.95635)	2.8655 (1.79540)
Low R&D intensity ind.	3.4618 * (1.84685)	3.5550 ** (2.12502)	2.6343 (1.71343)
Medium-low R&D intensity ind.	3.8436 (1.88710)	5.1500 *** (1.53125)	3.0857 (1.82985)
Medium-high and High R&D intensity ind.	4.4563 * (1.84669)	4.5349 * (1.80048)	3.1549 (1.88716)

Notes: (1) The classification of industries by R&D intensity is given in the text.
The results of the t-tests are based on comparisons of all outsourcers and non-outsourcers, and comparisons of outsourcers ≥ 25% (heavy outsourcers) and non-outsourcers. Standard deviations in parentheses.
(2) For definitions of variables, see Appendix 2 (PRODUCTION).
(3) Outsourcers which outsourced ≥ 25% of production in the last year (heavy outsourcers).
* Significant at 1% , ** significant at 5%, *** significant at 10%

Appendix 1

Advanced manufacturing technology

Computer-aided design (CAD) consists of the use of computer technology to aid in the design and, especially, the technical and engineering drawing of a product or part of it.

Computer-aided engineering (CAE) is an information technology used by engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis and repair.

Computer Aided Manufacturing (CAM) is a programming tool which allows physical models to be manufactured using computer-aided design (CAD) programs. Through the use of CAM, a factory can become highly automated, by employing systems such as real-time control and robotics. CAM can be used to facilitate mass customisation i.e. the process of creating many small batches of products that are custom designed to suit each particular client.

Flexible manufacturing systems (FMS) combine computer-managed numerical work stations where materials are automatically handled and machine loaded. They are adopted by firms to combine greater flexibility, and mass production with the benefits of unique products.

Computer numerical control (CNC) refers specifically to a computer "controller" which drives a machine used to fabricate components by the selective removal of material. Numerical control is a form of programmable automation.

Local Area Networks (LANs) are computer networks covering a small geographical area, such as a home, office or group of buildings.

Appendix 2. Definition of variables

Name of Variable	Definition	Question	Responses
ORGANISATION	Participation in production networks	Have you outsourced some production in the last three years?	Yes No
SIZE	Employment	No. of employees in the industrial plant	No. of employees in the industrial plant
OWNERSHIP	Origin of capital	Origin of capital	1.Domestic firm (1) 2. Subsidiary or joint venture (1)
MARKET	Characteristics of principal market (2)	How many firms compete in your principal market? (3)	1= a very small number of firms; 5= a very large number of firms
PRODUCTION	Type of production	Which statement better describes manufacturing in your plant?	1. We manufacture small batches and custom-made products 2.We manufacture large batches and employ continuous production
AGE (includes 4 variables)	Equipment age (includes standard equipment and AMT)	Please indicate the percentage of machines and equipment which are:	a) ≤ one year old b) 2-4 years old c) 5-10 years old d) > 10 years old
ADVANCED MANUFACTURING TECHNOLOGY			
i) Design and Engineering Technology			
CAD/CAE	Utilisation of Computer Assisted Design/Computer Assisted Engineering	Do you use CAD/CAE in your plant?	Yes No
CAD/CAM	Utilisation of Computer Assisted Design/Computer Assisted Manufacturing	Do you use CAD/CAM in your plant?	Yes No
CAD/PURCHASE	Utilisation of CAD for the processing of purchase orders	Do you use CAD to process your purchase orders?	Yes No
ii) Manufacturing Technology			
NC/CNC	Utilisation of Numeric Control/Computer Numeric Control	Do you use NC/CNC in your plant?	Yes No
FMC/FMS	Utilisation of Flexible Manufacturing Cell/Flexible Manufacturing Systems	Do you use FMC/FMS in your plant?	Yes No
LASER	Utilisation of laser technology for materials processing	Do you use lasers for the processing of materials?	Yes No
iii) Communication Technology			
LAN	Utilisation of Local Area Networks for information purposes	Do you use LANs for information?	Yes No
LAN FACTORY	Utilisation of Local Area Networks in the factory	Do you use LANs in your factory?	Yes No

Notes:

(1) Domestic firm: capital is 100 % Spanish. Subsidiary: foreign investment is ≥ 50% of total investment. Joint venture: foreign investment is < 50% of total investment.
(2) The principal market, defined by the volume of sales, can be regional, national or international.
(3) 1-5 Likert scale
(4) R&D includes basic research, applied research and product development.
(5) Products or processes are considered "new" to the company or industry even if they have been previously produced or implemented by other companies or industries.
(6) 1-10 Likert scale

Appendix 3

Outsourcers and Non-Outsourcers: Adoption of Advanced Manufacturing Technology, by R&D intensity of industry (1)

Percentage of firms agreeing with the following statements

Variable (2)	Statement	Outsourcers	Non-Outsourcers
TOTAL SAMPLE			
CAD/CAE	We use CAD/CAE	64.9 *	35.6
CAD/CAM	We use CAD/CAM	41.1 *	27.5
CAD/Purchases	We use CAD solutions for the processing of purchase orders	22.4 *	12.6
NC/CNC	We use NC/CNC	56.5 *	47.9
FMC/FMS	We use FMC/FMS	33.2 *	19.9
LASER	We use laser technology to process materials	14.6 ***	10.4
LAN COMM	We use LAN for communication	80.2 *	68.9
LAN FACTORY	We use LAN technology in the factory	76.3 *	63.9
LOW R&D INTENSITY INDUSTRIES			
CAD/CAE	We use CAD/CAE	55.4 *	24.9
CAD/CAM	We use CAD/CAM	37.8 **	27.1
CAD/Purchases	We use CAD solutions for the processing of purchase orders	18.1 ***	11.6
NC/CNC	We use NC/CNC	46.2	48.6
FMC/FMS	We use FMC/FMS	24.1 **	16.6
LASER	We use lasers	15.3	9.9
LAN	We use LAN for communication	76.7 ***	65.2
LAN FACTORY	We use LAN technology in the factory	72.7 *	58.6
MEDIUM-LOW R&D INTENSITY INDUSTRIES			
CAD/CAE	We use CAD/CAE	68.2 *	42.9
CAD/CAM	We use CAD/CAM	40.3 **	28.6
CAD/Purchases	We use CAD solutions for the processing of purchase orders	21.8 ***	13.3
NC/CNC	We use NC/CNC	66.4 *	47.6
FMC/FMS	We use FMC/FMS	28.9	21.0
LASER	We use laser technology for the processing of materials	9.5	12.4
LAN COMM	We use LAN for communication	76.8	75.2
LAN FACTORY	We use LAN technology in the factory	72.5	67.6
MEDIUM-HIGH AND HIGH R&D INTENSITY INDUSTRIES			
CAD/CAE	We use CAD/CAE	72.8 *	52.1
CAD/CAM	We use CAD/CAM	46.1 *	26.8
CAD/Purchases	We use CAD solutions for the processing of purchase orders	28.2 **	14.1
NC/CNC	We use NC/CNC	58.7 ***	46.5
FMC/FMS	We use FMC/FMS	48.5 *	26.8
LASER	We use laser technology for the processing of materials	18.9 **	8.5
LAN COMM	We use LAN for communication	87.9 *	69.0
LAN FACTORY	We use LAN technology in the factory	84.5 *	71.8

Source: Authors' calculations based on survey data.

Notes: (1) OECD classification of industries according to R&D intensity in the text.

(2) Definition of variables in Appendix 1.
* Significant at 1%; ** significant at 5%; *** significant at 10%
Chi-square results are based on comparisons of outsourcers and non-outsourcers.

[1] Flexibility may also include the firm's ability to change the quantity produced (adaptability), time needed, etc. (Morroni, 1991). These aspects are not analysed here.
[2] According to an econometric study of outsourcing in Spain, smaller companies are unlikely to engage in production outsourcing as outsourcers (clients) (Díaz-Mora, 2008). Such firms, according to the literature, are more likely to be involved in outsourcing arrangements as subcontractors (suppliers). Taking into account previous research, our sample does not include very small companies with fewer than 50 employees.
[3] Includes Wood, pulp, paper and printing; Food, beverages and tobacco; and Textiles, leather and footwear.
[4] Includes Building and repairing of ships; Rubber and plastics; Coke and refined petroleum; Other non-metallic mineral products; Basic metals and manufactured metal products.
[5] Includes Electrical machinery; Motor vehicles; Chemicals (excluding pharmaceuticals); Railroad equipment; and Machinery and equipment.
[6] Includes Aircraft and spacecraft; Pharmaceuticals; Office and computing machines; Radio, TV and communications equipment; Medical, precision and optical instruments. While the OECD classification has four categories, here the Medium-High and High R&D intensity classes were collapsed to avoid thin cells in cross-tabulations.
[7] Insufficient capacity, cost reduction and flexibility were mentioned as the most important.
[8] Available upon request.
[9] Here, we confine the analysis to a comparison between Outsourcers and Non-Outsourcers. Owing to the presence of some thin cells in cross-tabulations, we do not specifically analyse Heavy Outsourcers.
[10] Available upon request.