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AN ANALYSIS OF SUB-CONTRACTING RELATIONSHIPS BASED ON THE SUB-CONTRACTOR/CUSTOMER TECHNOLOGY EXCHANGE PORTFOLIO: SOME EMPIRICAL FINDINGS*

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ABSTRACT

In the last decade, subcontracting relationships have assumed a particular weight in the strategy of managers searching for efficiency, flexibility, and quality. Subcontracting is not a new industrial practice. Reasons and ways firms' recourse to it have changed. Exchange relationships have become highly complex in their nature. In order to manage complexity, multiple channels for the coordination of the activities are developed, and an intensive exchange of technology is established. This paper reports some findings of an empirical exploratory study aimed at investigating the nature of technology flow in the customer firm/subcontractor interaction. A sample of Italian small and medium subcontractors was considered.

INTRODUCTION

In the last few years, collaborative agreements between entrepreneurial firms and large companies have become increasingly common. Subcontracting is a frequent form of cooperation in which a small- or medium-sized firm produces parts for a large final manufacturer or performs operations for that producer as a wage work (Lazerson, 1990). These relationships exist in almost every industrial sector. They are common in industries characterized by complex products, some of which involve thousands of components (i.e., automobile, aircraft and tool machine manufacturing). By using a pool of external suppliers a greater flexibility can be combined with a constant high productivity. Sharing production among firms determines a division of technological areas of specialization, and the subcontracting system becomes a distribution channel for technical knowledge, routines and procedures transfer, and organizational learning for small firms.

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Considering the foregoing discussion, an interesting research question arises. That is, "What kind of relationship exists between the nature of the technological flow of the customer firm or subcontractor business exchange, and product and subcontractor's characteristics?"

AN OPERATIONAL CONCEPT OF TECHNOLOGY

A firm's technology is the set of technologies that it utilizes to carry on its activities. This set of technological competencies and capabilities continuously modifies as the result of efforts of internal or external development. Technology can be embedded in the individuals, in the structure and culture of organizations, in its records and routines, or in its equipment (Hayes & Wheelwright, 1984). Diverse modes of organizational learning convert individual expertise and knowledge into organizational technologies. According to Nelson and Winter (1982), firms develop routines that reflect the organization's ability to adapt to changing circumstances and establish distinctive capabilities and skills.

Unfortunately, technology sometimes remains an ambiguous concept, difficult to operationalize. A way to overcome this difficulty is to break it down to its basic components. In this paper, a definition of technology adapted from that proposed by the Technology Atlas Team (1987) is used. Four basic components of technology are identified: hardware (HW), object-embodied technology; human skill (HS), people-embodied technology, which is the know how of carrying out tasks; information (IN), document-embodied technology; rules and procedures (RP), institution embodied technology. This latter establishes the nature and sequence of the information flows, machines to be used, and skills required.

Table 1 reports the classification used. This taxonomy allows the analysis of how technology flows among firms and the ways a subcontractor can internalize new technology.

Table 1

The Four Components of Technology

Technology hardware-embodied (HW)	It is in form of equipment, machines, tools.
Technology document-embodied (IN)	It is in form of manuals, designs, schemes. It describes how to use a single object. It is always codified.
Technology people-embodied (HS)	It is in form of judgements, opinions, suggestions, impressions, skills. It is not codifiable and transferable only through people.
Technology rule-procedure embodied (RP)	It is in form of scheduling plans, procedures, organizational rules. It establishes what kind of relations exist among HW, IN, HS for task execution. It can be formalized and codifiable with a different degree.

TECHNOLOGY TRANSFER, ADAPTATION, AND COORDINATION MECHANISMS

Subcontractors and customers often establish lasting collaborative relationships, and when the business exchange accounts for a relevant share of subcontractor sales or customer's needs, a significant adaptation process occurs (Hallen, Johanson, & Seyed-Mohamed, 1991). This adaptation develops both as a process of organizational fit and as a process of day-by-day coordination.

The process of fit between customer and subcontractor is necessary to establish a common language to make effective communication between the two parties. It allows an increase in the technological capability of one of the parties involved, and to make it homogeneous and compatible with that of the other. This adaptation usually requires a substantial modification for the organizations involved, and considerable investments, so to increase dependence between the parties. The subcontractor can adapt its manufacturing process to that of its customer by purchasing equipment which can use part programs for Numerically Controlled (NC)[1] machines created by the customer, by introducing logistic systems, common scheduling and planning procedures, and routines for quality control. The other form of adaptation almost occurs on a day-by-day base, with the coordination of the subcontractor's operations with those of its customer. Coordination is necessary to cope with the uncertainty, ambiguity, and inter-dependence of the system, arising from the absence of information or the presence of conflicting interpretations of a situation, and the organization of productive system (Galbraith, 1973; Thompson, 1967, & Weick, 1979). In order to reduce uncertainty and ambiguity and cope with the system inter-dependence, organizations have to transfer and process information (Daft & Lengel, 1986). The adaptation and coordination mechanisms represent effective means for the transfer of technology across firms.

Empirical research aimed at studying the interaction between small and large firms identified 11 channels frequently used by firms to transfer technology (Esposito & Raffa, 1991): raw materials, sub-components and pre-machined parts, machinery and equipment, training, advice on specific issues, in-progress check, advice for the adoption of quality routines, quality management procedures, meetings, documents, and different forms of collaboration at the start of the transaction. These channels transfer technology under the four forms described.

METHODOLOGY

Data were collected through face-to-face interviews with entrepreneurs, technicians, and plant managers from the end of 1990 to 1991. According to the author's experience, a structured face-to-face interview approach can yield more reliable data. It allows the interviewer to elaborate on those questions that might cause difficulty, and to gain a visual impression of the object of the survey. Each respondent was interviewed by means of a questionnaire seeking data on economic and other firm characteristics, such as location, sales, employment, technical/manufacturing capability, and interaction modes with the main customers.

A sample of 59 subcontracting firms was studied in depth. All firms investigated are located in Italy. They subcontract to customers selling in the aerospace/electronics, automotive, and medium-low technology industries (electrotechnology, tool machine building, textile-machine).

[1] *NC is a system for the automation of variable work phases on metalworking machine tools.*

The average size of a sample's firm is 82.1 employees (sd = 112.7), sales per year 13.234 billions of Lira (sd = 29.37).

Every subcontracting transaction is characterized by a certain combination of the four technology components. This combination determines the technological portfolio of the customer/subcontractor exchange. The model of the technology transfer channels proposed by Esposito and Raffa (1991) is used here to study the nature of technology transfer from a customer to its subcontractor, and identify the technological portfolio.

Each respondent was asked to judge the importance and utility of each channel to transfer technology into his factory on a value scale from 1 to 9. According to Saaty (1980), this scale captures fairly well the preferences of an individual. Every channel vehicles technology in the form of hardware, skills, information, and organizational rules and procedures at a different rate. In order to measure how each channel affects every component, a major assumption was introduced—that the influence of the flow of technology along the channel on each technology component was given by the following relation:

$TCi = [S (wIj\ Cj + wIIj\ Cj+..]/Vmaxi$

$j = 1, ..., 11$ where

TCi is the generic technology component

Cj is the utility-value given to channel j by the respondent

$Vmaxi$ is the maximum possible value for the channels influencing that component

wj is a weight measuring the magnitude of the effect of that channel on the component i

wIj measures 1st order effects, $wIIj$ measures 2nd order effects, and so on.

Some discussion with business consultants, entrepreneurs, and firms managers made it possible to build a matrix of weights accounting for the contribution of the channels of technology transfer to each component of technology. A "pairwise comparisons" approach common in the Analytic Hierarchy Process (AHP) technique was used to determine weights.[2] A second assumption was done, that all the effects were of the first order. Consequently, only wIj values were considered. The mapping of the relational system for the evaluation of the technological portfolio is reported in the Appendix.

Cluster analysis was used to group firms, using as the clustering variables the four components of technology. The K-Means algorithm proposed by MacQueen was used as clustering technique. Because the algorithm required to specify in advance the number of clusters (K), the software program was made rerun for various choices of K in order to obtain K not repetitive combinations of technology component measurements having the highest F-values. For every subcontractor, its first and second customers were considered. On average the sales for the first two customers account for more than 65 percent of total sales. In order to take into account the volume of the business exchange, the flow of technology from the customers was weighed with the percentage of sales. Analysis of Variance (ANOVA) was used to test the difference between the four clusters.

[2] *AHP is a technique developed to find priorities of different alternatives relative to an object reducing a sequence of priority problems into a sequence of pairwise comparisons according to certain criteria (10;6). In this case the criteria were the four technology components, the alternatives the 11 channels of technology transfer.*

RESEARCH FINDINGS

Table 2 shows the correlation matrix among the values of technology components for the main two customers. A compensation effect between some components of technology emerges. Particularly, an increase of HW determines a decrease of IN and, with a lower intensity, a decrease of HS. Generally, the more technology is transferred lending specific equipment and specialized machinery to the subcontractor, or providing it with the raw materials, the less it is necessary to transfer a rich written technical documentation. As an illustration, let us think of a firm that receives a die and the raw material to make plastic moldings from the customer. This firm will need only some indications about how to blend the plastic powders, the value of temperature, and the number of pieces to produce. The same is for people-embodied technology. The stronger is the weight of the physical component of technology, the less relevant is the weight of people. In the same way, an increase in the value of HS determines a decrease in RP (and vice versa). This is particularly true when organizational rules and procedures are easy to be codified, and after being transferred into a firm, they become routines. That is the case of the procedures a firm must implement to manage quality control. This compensation effect among the components of technology remains considering the relationship with each customer separately. The outcomes from cluster analysis confirm this compensation effect.

Table 2

Correlation Matrix of the Technology Components—First and Second Customer

	HW	IN	HS	RP
HW	1.000 (0.000)			
IN	-0.734 (0.000)	1.000 (0.000)		
HS	- 0.542 (0.000)	0.148 (0.263)	1.000 (0.000)	
RP	- 0.313 (0.016)	0.184 (0.162)	-0.522 (0.000)	1.000 (0.000)

Source: database ODISSEO
Note: probabilities are in brackets
Bartlett-Chi Square Statistic: 621.018 Prob= 0.000

Table 3 illustrates what happens to the four technology components passing from the first to the second customer. The variables considered in the correlation were obtained as the difference between the values of each technology component for the first two customers, then normalized by dividing it for the maximum value of the technology component. Technology components tend to vary in the same direction. An increase in the flow of technology in one of the four forms determines an increase in the flow in the other three forms.

Table 3

Correlation Matrix of the Difference of Values of Technology Components Between the First and Second Customer

	DHW12	DIN12	DHS12	DRP12
DHW12	1.000 (0.000)			
DIN12	0.357 (0.033)	1.000 (0.000)		
DHS12	0.393 (0.013)	0.940 (0.000)	1.000 (0.000)	
DRP12	0.339 (0.051)	0.947 (0.000)	0.888 (0.000)	1.000 (0.000)

Source: database ODISSEO
Bartlett-Chi Square Statistic: 255.834 Prob= 0.000
Note: probabilities are in brackets

Firms' Characteristics, Product And Market Strategies

By means of cluster analysis four kinds of subcontracting relationships were identified, depending on the feasible combination of the four technology components. Summary statistics for the four clusters are shown in Table 4.

Table 4

Summary Statistics for the Four Clusters of Firms

Variable	DF	DF	F-Ratio	Prob
Hardware	3	55	108.61	0.000
Written Information	3	55	15.22	0.000
Human Skill	3	55	61.85	0.000
Rules and Procedures	3	55	25.31	0.000

Source: database ODISSEO

The four clusters show four diverse combinations of the components of technology which indicate four types of technological portfolios (Table 5).

Table 5

Technological Portfolio and Firms' Characteristics

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Anova
Total of firms = 59	n = 31	n = 15	n = 7	n = 6	*p*
	HW = .03 IN = .35 HS = .29 RP = .33	HW = .22 IN = .28 HS = .19 RP = .30	HW = .05 IN = .38 HS = .07 RP = .51	HW = .35 IN = .25 HS = .07 RP = .33	
AGE (years)	31.00	19.40	27.33	17.33	0.013
SIZE (employees)	255.42	43.5	23.0	29.3	0.489
SALES (£billion)	24.58	3.67	2.68	2.187	0.065
INSALES (%)	0.16	0.21	0.17	0.36	0.185
SALEMP	0.128	0.080	0.104	0.072	0.001
%PR1	0.63	0.67	0.79	0.5	0.008
%PR123	0.92	0.97	0.92	0.89	0.413
REGMARK	0.53	0.75	0.74	0.87	0.006
ITAMARK	0.87	0.96	0.96	0.88	0.243
%CU12	0.69	0.76	0.57	0.83	0.034
FTECH1	1.712	2.408	1.134	1.522	0.001
FTECH2	1.270	1.805	0.652	1.061	0.041
DFTECH12	1.571	2.278	1.044	1.412	0.002
DCOMP12	0.142	0.096	0.98	0.019	0.05
DCOMP1234	0.370	0.480	0.222	0.648	0.135

Source: database ODISSEO

In the first cluster, hardware embodied technology is not relevant. On the contrary, technology embodied as information and rules and procedures has a higher weight and technology transferred through people is much more important than in the other clusters. Most firms belonging to this cluster are main contractors in the automotive industry. These firms are involved in the development of a new model from the early stage in co-design with the customer. In this stage there are still problems that must be solved and uncertainty is high. Consequently, establishing an intense communication between customer and subcontractor design teams becomes a strong imperative for an effective development process. Three firms subcontract to the electronic industry.

The second cluster presents a more balanced exchange technological portfolio, even though the rules/procedures component has a slightly higher weight relative to the others. Some primary firms subcontractors to the aerospace/defense industry are in this cluster. Two firms are second-tier subcontractors for the aerospace industry. One is a second tier subcontractor to the automotive industry.

The third cluster contains firms having an unbalanced exchange technological portfolio in which information and rules/procedures prevail. Generally, firms belonging to this cluster are subcontractors to traditional low-medium technology industrial sectors (electrotechnology, textile-machinery building). These firms do not establish stable and constant relationships with their customers. Consequently, when they begin to collaborate with a new customer there are no incentives for this to transfer a relevant amount of technology to the subcontractor factory, such as practices for quality management, costs evaluation methods, and scheduling plans. Common standards and routines cannot be established and a large amount of codified technology must be transferred in every transaction. That explains the relative high value for information and rules.

The last cluster is comprised of small firms subcontracting almost exclusively to the aerospace and defense industry. Technology embodied in raw material and specific equipment is relevant in this cluster. These firms receive pre-machined parts to manufacture fixtures, jigs, and gauges from the customer. A high level of standardization supports the transaction making it effective.

Firms belonging to the first cluster are, on average, older and larger. Thirty-one years is the average age (AGE) for these firms. On average, their size (SIZE) is 255 employees and 24.58 billion of lire as sales per year (SALES) (no statistical evidence supports this). As an indicator of success, the average firm's growth in sales over the last three years was chosen (INSALES). The values of this variable show that the small firms of the fourth cluster in 1990-91 were faster growing than the other firms. The positive demand trend of the aerospace industry in that period probably produced a "driving effect" on them.

The investigated firms primarily serve Italian markets (ITAMARK), which represent almost the exclusive markets for firms in the second and third clusters (96 percent). Firms of the fourth cluster have plants that are localized close to their customers. Thus, their regional market (REGMARK) coincides with the Italian market. At the same time, they have international customers as firms of the first cluster. The internationalization process of the firms belonging to these two clusters has a different origin. The belonging to international groups favored the entrance into foreign markets of the automotive component subcontractors of the first cluster, which established collaborative relationships with the competitors of their main Italian customer. Firms of the fourth cluster entered foreign markets primarily thanks to the international collaborative agreements engaged by their Italian customers. In both cases, this process of internationalization supported a circulation of technology in the subcontracting chains.

A relatively high dependence on a few major customers and a certain product specialization characterize these firms. Firms of the third cluster present a lower dependence on the first customer (%CU1) than other firms. They derive less than 40 percent of their sales from their first customer and less than 60 percent from their first two customers (%CU12). These firms had short-term contractual agreements with their customers. These results support that a high importance given to procedures during the transaction is a consequence of a low dependence on the customer and a scarce initial fit also, an idea that emerged from the analysis of the exchange technological portfolio. On the contrary, these firms follow a strategy of product specialization. The 79 percent of the total sales is derived from only one line of products (%PR1). There are no substantial differences between firms of the first and second clusters as regards dependence on the customer. Firms of the fourth cluster are highly dependent on the first two customers, which sell in the same industry, but on the contrary, are less product specialized. These firms are small family-owned machine shops. Indeed, 29 employees and 2.187 billions of lire represent the average size. The low ratio of sales to employees (SALEMP) can be explained by the fact that these firms receive from the customer the raw materials, or pre-machined parts, the cost of which is not included in the sales evaluation. These firms largely invested in numerically controlled equipment (usually, single NC machines or centers) in the last three years. The flexibility of the new technology made it possible for these firms to diversify production gaining efficiency.

During the interview, respondents were asked to rate the technological sophistication of the product manufactured for the first three main customers on a 1-9 scale. To assess product technological sophistication, the following dimensions were considered: the level of conformity to quality specs requested by the customer for that product; the level of difficulty in realizing it; and the time required to learn how to do that product with the required degree of quality. To limit the effects of the subjectivity of judgments, the analysis was done considering the difference between the values of technological sophistication of products manufactured for the two main customers. This value was normalized by dividing it for the maximum score rate given by the respondent (DCOMP12). From the analysis, it emerges that there is no significant difference between the technological sophistication of the product realized for the first two customers in the case of firms belonging to the first, second, and fourth clusters. Differences become higher passing from the product realized for the first two customers to products realized for the other customers. That is particularly the case of firms in the fourth cluster. These firms have the first two customers in the aerospace industry, while the others are in low technology industries. Some strategies of technological diversification can be thus identified. Firms in the second and fourth clusters pursue almost the same strategy. Indeed, most of the firms of the second cluster are subcontractors of the aerospace industry while all the firms of the fourth cluster subcontract to the aerospace industry.

Technology flow largely increases with product sophistication as shown in Table 6. It appears that manufacturing more sophisticated products requires a deeper integration with the customer.

Table 6

Relation Between Technology Flow and Product Technological Sophistication: First and Second Customer.

Dependent variable:

DFTECH12 N = 56

Squared R = 0.443; no

constant

variable	coefficient	std error	probability (2 tail)
DCOMP12	2.637	0.670	0.004

Source: database ODISSEO
Note: In the sample 56 firms have more than one customer.

In the four clusters, the technological flow from the first customer (FTECH1) is considered more important than the flow from the second customer (FTECH2) in the acquisition of technological capabilities. The calculated values for the difference (DFTECH12) confirm this tendency. It is interesting to note how the values for both the flows are lower in the case of firms belonging to the third cluster.

CONCLUSIONS

This study is exploratory. Further investigation is required to assess the validity of the considerations done. Several caveats should be identified before drawing any conclusion.

First, findings rely on subjective judgments and key variables are built from these judgments. A major effort should be undertaken to use a more objective scale to measure variables and more effective and objective methods to assign attribute weights.

Second, a more stratified and larger sample should be chosen. The number of firms subcontracting to the aerospace and automotive industry is high relative to the firms subcontracting to other industrial sectors. Additionally, cross-cultural studies are necessary to determine if the results can be generalized to other countries.

Finally, a more reliable and sophisticated statistical analysis should be conducted. Cluster analysis remains an exploratory tool.

Nevertheless, the study provides the basis for more refined research that can enable researchers to provide useful guidelines for subcontracting and customer firm's technicians and managers to better model their collaborative relationships. To summarize, findings presented in this paper suggest these main conclusions. The customer firm, in different ways, enables its subcontractors to achieve a higher technological capability. The constant request of better manufacturing performances and more sophisticated parts supplied, together with an intense technological flow, contribute to the upgrading of the subcontract's technological asset. The need to be more integrated with the customers, to increase efficiency, and particularly to increase product reliability and quality forced these firms to largely implement new production technology and to focus on new manufacturing methods. The deeper is the integration between the customer and the subcontractor, the more intense is the technological flow between the parties. This finding seems to confirm what emerged in other studies. A higher involvement in the process of product development and manufacturing determines, but at the same time needs, a more intense and articulated flow of technology between the parties. In some industries, customer/subcontractor transactions assume particular characteristics and the technological content of the arrangement depends on the characteristics of the subcontracting firms.

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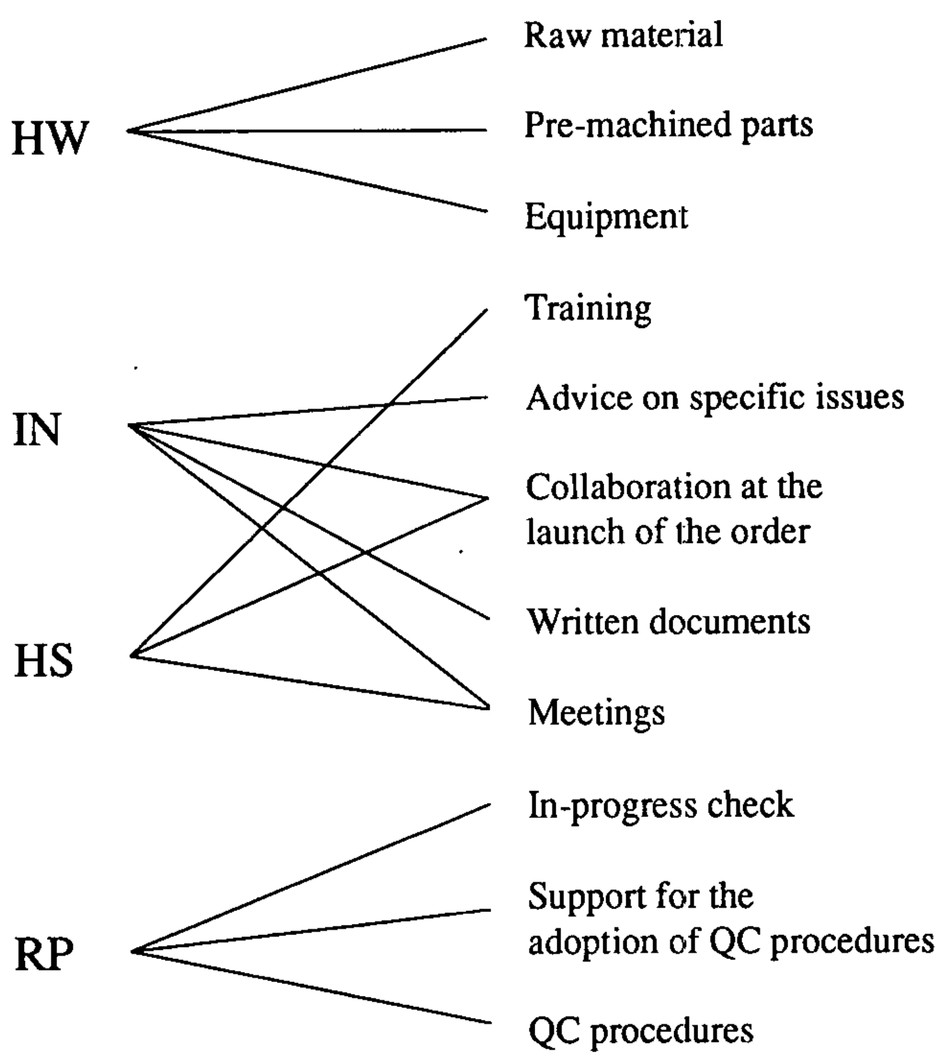
APPENDIX

Channels to Technology Components Contribution Map



Scale used to assess contribution weights:
1: no contribution at all
100: highest contribution