



THE CREATION OF A MIDDLE-MANAGEMENT LEVEL BY  
ENTREPRENEURIAL VENTURES: TESTING ECONOMIC  
THEORIES OF ORGANIZATIONAL DESIGN

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*Why do some entrepreneurial ventures rapidly switch from flat organizations composed of owner-managers and line workers to deeper organizations that also include a middle-management level? The aim of this paper is to investigate this issue and to test the predictions of different streams of the theoretical economic literature on organizational design. We use the estimates of survival data analysis models to examine the determinants of the addition of a middle-management level to the corporate hierarchy of a large sample of Italian high-tech entrepreneurial ventures. The econometric results lend support to the view proposed by the "information processing" stream that the information overload problems engendered by a highly competitive and unpredictable business environment are key drivers of the creation of a middle-management level. Moreover, in accordance with the "knowledge hierarchy" literature, the greater the human capital of firms' owner-managers, the more likely the appointment of a middle manager. Conversely, we fail to provide evidence consistent with theoretical predictions inspired by the "decentralization of incentives" stream. Lastly, transaction costs and adverse selection problems in the managerial labour market are found to have a large negative effect on the likelihood of the appointment of middle managers.*

## 1. INTRODUCTION

Since the seminal work of Simon (1962), scholars in the economics of organization have described the firm as a *hierarchical system*: that is, a system that is composed of interrelated subsystems, each of the latter being, in turn, *hierarchical* in structure until we reach some lowest level of elementary subsystem. The *depth* of the corporate hierarchy measured

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by the number of hierarchical levels between the top and the bottom of the organization (i.e., between top managers and line workers) is a crucial characteristic of organizational design that has attracted a rich stream of theoretical research.<sup>1</sup> Empirical work in this area dates back to the pioneer empirical studies of the Aston group in the 1960s (Pugh et al., 1963, 1968, 1969; Hickson et al., 1969. See also Child, 1972), but has fallen behind theoretical developments. Only a few large-scale econometric studies have examined factors that determine the depth of firms' corporate hierarchy, focusing attention on incumbent, generally large sized firms (Delmastro, 2002; Rajan and Wulf, 2006; Wang, 2009; Guadalupe and Wulf, 2010. See Colombo and Delmastro, 2008, chapter 3 for a review of the early empirical literature).

In this work, we depart from this stream of literature in that we analyse the introduction of a middle-management layer in the corporate hierarchy of *owner-managed entrepreneurial ventures*. In particular, we are concerned with two research questions. First, we investigate "demand side" factors that shape the decision of firms' owner-managers to switch from flat organizations composed only of owner-managers and line workers to deeper ones that also include a middle-management level. Second, provided that owner-managers are willing to create a middle-management position, we examine "supply side" factors associated with imperfections in the managerial labor market that make the implementation of this decision difficult. In the empirical part of the paper, we analyse the determinants of the introduction of a middle-management level into the corporate hierarchy of a large sample of Italian high-tech entrepreneurial ventures. We estimate several survival data analysis models and we consider a large set of entrepreneur-, firm-, and industry-specific explanatory variables, with the aim of testing the predictive power of different streams of the theoretical economic literature.

This work originally contributes to the economic literature on organizational design. As far as we know, this is the first econometric study that focuses attention on the depth of the corporate hierarchy of entrepreneurial ventures. There are important advantages to examining how rapidly a middle manager is appointed by an owner-managed entrepreneurial venture starting from its founding. First, all of these firms begin operations with a two-layer corporate hierarchy. We analyse factors driving the addition of one layer (i.e., the switch to a three-layer hierarchy). Hence, the change in the depth of the corporate hierarchy is the same for all firms and problems engendered by the heterogeneity of the dependent variable in studies that examine incumbent firms experiencing different types of changes in the depth of the corporate hierarchy, are avoided. Second, inertial forces that make the depth of the corporate hierarchy path dependent are weaker at the beginning of firms' operations (Hannan and Freeman, 1984, p. 157). Therefore the confounding effect of organizational inertia is more limited here than in most previous studies on these issues.<sup>2</sup> The drawback is clearly that our findings may not be generalizable to other types of firms or to other changes of the depth of the corporate hierarchy. Lastly, as far as we know, the role of imperfections in the managerial

1. As to our knowledge, Williamson (1967) represents the first theoretical attempt to model the firm as a hierarchy.

2. Baron et al. (1999a) and (1999b) argue that increases in the managerial intensity of entrepreneurial ventures, and thus in the depth of their corporate hierarchy, are influenced by the organisational model or "blueprint" espoused by the founders in creating the new enterprise. This may be a source of path-dependency in the present study. In the empirical analysis, we consider the characteristics of firms' founders (i.e., their number, human capital and managerial and entrepreneurial experience). Unfortunately, we do not have information on founders' blueprints. We acknowledge this as a limitation of our study. Our point is that problems arising from path dependency are less severe here than in previous studies of the depth of firms' corporate hierarchy.

labor market has been neglected in previous studies of the determinants of the depth of firms' corporate hierarchy. This is an important gap in the literature. The large costs that entrepreneurial ventures allegedly incur in recruiting middle managers in comparison with large established firms mean that the deepening of their corporate hierarchy would command a great marginal product. In accordance with the insights provided by the resource reallocation literature (see Hsieh and Klenow, 2009 for a recent contribution. See Caselli and Gennaioli, 2005, for a model of inefficiencies in the allocation of managerial talent based on agency considerations), this deepening, and the associated reallocation of middle managers from established firms to entrepreneurial ventures may result in a considerable rise of aggregate total factor productivity. Therefore, understanding when and how middle-management positions are created by entrepreneurial ventures may help in removing obstacles in this direction.

This work is also an original addition to the literature on the economics of entrepreneurship. With few notable exceptions (Baron et al., 1996, 1999a, 1999b), organizational design issues relating to the managerial professionalization of entrepreneurial ventures have been underresearched in this literature. Previous studies indeed have examined the replacement of founder-CEO by a "professional" top manager (e.g., Boeker and Karichalil, 2002; Wasserman, 2003) and the organization of the top management teams of entrepreneurial ventures (e.g., Ucbasaran et al., 2003; Sine and Kirsch, 2006). However, the creation of a middle-management level and the associated formal delegation of (some) decision authority to a professional salaried manager is a fundamental transformation of the organization of entrepreneurial ventures that has been neglected by the extant literature.<sup>3</sup> Therefore, investigating factors that speed it up is of obvious interest.

The paper proceeds as follows. In Section 2, we present the theoretical background and develop a simple model highlighting factors that favor or hinder the creation of a middle-management level in a two-layer owner-managed entrepreneurial venture. Then in Section 3, we describe the dataset used in the econometric analysis and provide some descriptive statistics on the "managerial professionalization" of Italian high-tech entrepreneurial ventures. In Section 4, we specify the econometric models, introduce the explanatory variables, and describe the results of the econometric analysis. Some summarising remarks in Section 5 conclude the paper.

## 2. THEORY

### 2.1 THEORETICAL BACKGROUND

In this work, we consider the transformation of the organization of an owner-managed firm from a flat hierarchy composed only of two levels (i.e., the owner-manager(s) and line workers), with all decisions concentrated at the top of the hierarchy, to one that also includes an intermediate middle-management level (i.e., a three-layer hierarchy). This transformation involves formal delegation of (some) decision authority to the newly

3. Bertoni et al. (2011) document that the creation of a middle-management level positively influences the growth rate of Italian high-tech entrepreneurial ventures. We are not aware of other large scale econometric studies on this issue. However, both qualitative and quantitative studies in the entrepreneurship literature suggest that lack of managerial resources represents a key bottleneck for the development of this type of firms (e.g. Greiner 1972) and their managerial professionalisation is likely to result in greater firm performances (e.g. Davila et al. 2010).

appointed middle manager.<sup>4</sup> Two streams of the economics of organizational design literature provide useful insights into the issue under consideration here: the “information processing” and “decentralization of incentives” streams.

The *information-processing* stream, while neglecting agency problems, emphasises that all individuals inherently have a limited capacity to acquire, store, process, and transmit information (Simon, 1945). Hence, for a owner-managed two-layer firm the addition of a middle-management level leads to an improvement of information processing capabilities, entailing two advantages.

First, *information overload* problems that hurt the decision-making activity within the firm are alleviated. The concentration of all decisions with the owner-manager in a two-layer hierarchy reduces the number of decisions that are made per unit of time in comparison with a situation in which some decisions are decentralised to middle managers and made concurrently (Keren and Levhari, 1983, 1989; Radner, 1993; Van Zandt, 1998. See also Radner, 1992).

Second, a three-layer hierarchy “protects” the owner-manager as she avoids wasting her valuable time on low-value-added decisions that can be delegated to middle managers (Harris and Raviv, 2002). In accordance with this view, Garicano (2000) argues that a pyramidal “*knowledge hierarchy*” in which (i) higher-rank individuals (i.e., owner-managers) specialise in solving difficult (i.e., strategic) problems that lower-rank individuals (i.e., middle managers) are not able to solve, and (ii) these latter individuals are assigned responsibility for solving simpler (i.e., operational) problems, allows a firm to optimally use the skills of owner-managers (see also Garicano and Rossi-Harsberg, 2006).

Conversely, the *decentralisation of incentives* stream brings to the fore the divergence of objectives between firms’ owner-managers and salaried employees. Initially, this literature focused attention on the principal-agent relation between the owner-manager and line workers. While assuming that the objectives of middle managers are aligned with those of the principal, it highlighted the monitoring advantage of appointing a middle manager that arise from the reduction of the average span of control (i.e., the number of line-workers per manager. See Keren and Levhari, 1979; Calvo and Wellisz, 1978, 1979; Qian, 1994).

More recently, emphasis was placed on the improvement in the *quality of decisions* made possible by the creation of a middle-management level. Employees often possess personal *specific knowledge* (Jensen and Meckling, 1992) that gives them an information advantage over the owner-manager in some matters.<sup>5</sup> For effective decisions to be made, this specific knowledge needs to be co-located with decision-making authority.<sup>6</sup> In a two-layer corporate hierarchy with all decisions concentrated in the hands of the

4. Empirical studies generally find a positive correlation between the depth of the corporate hierarchy and the delegation of decision authority (see Colombo and Delmastro 2008, Ch. 3).

5. For instance, the owner-manager of an entrepreneurial venture may have sophisticated technical skills but lack any commercial experience. A seasoned salesman with industry-specific commercial expertise clearly enjoys an information advantage over the owner-manager in identifying how to promote the new products that the firm is developing and attract interested potential customers. The neglect of the agent’s information advantage was recognized as a serious weakness of traditional agency theory in Holmstrom’s (1979, p. 88) seminal paper.

6. This idea dates back to Hayek’s (1945) seminal work on the use of knowledge in society. “If we . . . agree that the economic problem of society is mainly one of rapid adaptation to changes in particular circumstances of time and place, . . . decisions must be left to the people who are familiar with these circumstances, who know directly of the relevant changes and of the resources immediately available to meet them. . . . We must solve it by some form of decentralization” (Hayek 1945, p. 524. See also the extensive discussion of this issue in Jensen and Meckling 1992).

owner-manager, employees must transmit the information underlying this specific knowledge upwards on the corporate ladder. However, employees' individual objectives are likely to diverge from those of the owner-manager, as employees obtain private (nonmonetary) benefits from decisions (Aghion and Tirole, 1997). If the information communicated by employees cannot be verified by the owner-manager (i.e., it is "soft," Stein, 2002), employees will be inclined to communicate it strategically so as to influence the decisions of the owner-manager to their own advantage (Dessein, 2002). Because the owner-manager knows that the information transmitted by employees is biased, she will give it scarce consideration in her decision-making. The ensuing *loss of information* makes decision-making in a two-layer hierarchy inefficient. Loss of information problems can be avoided if the owner-manager appoints employees who possess relevant specific knowledge as middle managers and delegate (some) decision authority to them (Aghion and Tirole, 1997; Baker et al., 1999; Dessein, 2002). The drawback of this move lies in the owner-manager's *loss of control* over firm's operations and the divergence of the decisions made by middle managers from those that are optimal to the owner-manager. Both the loss of information problems that occur in a two-layer hierarchy and the loss of control problems engendered by the switch to a three-layer hierarchy can be alleviated through the use of "high-powered" incentives that tie the rewards allotted to firm personnel to firm performance. The delegation literature (Dessein, 2002; Alonso et al., 2008; Rantakari, 2008a) shows that high-powered incentives are more effective in reducing loss of control than loss of information problems and therefore are a complement of the delegation of decision authority associated with the creation of a middle-management level.<sup>7</sup> Loss of control problems can also be mitigated if the owner-manager closely monitors the decisions made by middle managers.

Lastly, there are imperfections in the managerial labour market that may make it difficult for an entrepreneurial firm to appoint a middle manager unless a suitable individual can be found among firm's personnel. First, an entrepreneurial firm is likely to incur substantial transaction costs in the search for and selection of suitable candidates for a middle manager position. Second, the selected candidates may find the firm's employment offer quite unappealing. The financial literature has pointed out that due to information asymmetries, it is generally difficult for outsiders to assess the "quality" of the projects of an entrepreneurial firm; the associated adverse selection problems make it difficult for the firm to raise external finance (see e.g., Carpenter and Petersen, 2002). Similar problems are encountered in hiring a middle manager. Middle manager candidates may not be able to assess a firm's future prospects. If they accept firm's employment offer, they commit their human capital to the firm and need to make firm-specific relational investments which lose most of their value out of this employment relation.<sup>8</sup> Unless the entrepreneurial firm is

7. The intuition behind this result is that under centralization, employees will reveal the truth to the owner-manager only when the recommended actions go in the direction of their bias. In other words, in spite of the incentives, employees will abstain from sending non-noisy messages so as not to reveal to the owner-manager the nature of their bias. The above argument is in line with the Delegation Principle (Milgrom and Roberts 1992) according to which decision rights should be assigned to the best-informed agents provided that their objectives are sufficiently aligned with those of the principal. For empirical evidence of the complementarities between delegation and high-powered incentives, see Colombo and Delmastro (2004), Foss and Laursen (2005), Wulf (2007), Meagher and Wait (2008).

8. For instance, a sales manager needs to become acquainted with the products of the entrepreneurial venture to be able to assess their market potential and find suitable potential customers. If these products are based on innovative proprietary technologies, the personal investments that the sales manager needs to make in terms of effort and attention are firm-specific and are almost useless out of this employment relation.

able to credibly “signal” its quality to middle manager candidates (Spence, 1973), it may prove impossible for the firm to fill the middle-management position it wants to create. The firm will then be forced to retain a flat (and suboptimal) two-layer hierarchy.

## 2.2 AN INFORMATION PROCESSING MODEL

In this section, we present a simple model inspired by the information processing stream, of the creation of a middle-management layer by a two-layer owner-managed entrepreneurial venture. Agency considerations will be introduced in the following section. Here, we assume that (i) the main benefit of recruiting a middle manager arises from the increased ability of the firm to process information, and (ii) the objectives of the middle manager are perfectly aligned with those of the owner-manager. We also assume that (iii) owner-managers are able to perform all tasks performed by middle managers and some more tasks.

Following Harris and Raviv (2002), we model the firm as consisting of four operating activities: production of products ALFA and BETA—that are labelled as activities A and C, and commercialisation of the two products (activities B and D). Activities may interact with one another. There are four possible pairwise interactions that we label AB, CD, AC, and BD. In other words, we assume that there are potential benefits both in coordinating the production and commercialization of each product (AB and CD) and in coordinating production and commercialization across products (AC and BD). For a more detailed discussion, see again Harris and Raviv (2002, pp. 856–857). Middle managers are capable of detecting and exploiting one particular interaction, which without loss of generality is BD (i.e., commercialisation of the two products). Owner-managers are capable of (i) detecting and exploiting all pairwise interactions, including BD, (ii) detecting and exploiting the company-wide interaction ABCD that middle managers cannot detect; and (iii) performing other high-value added strategic tasks, like managing development of new products or entry into new markets, which middle managers again cannot perform.

The expected benefit from coordinating each pairwise interaction is equal to the probability  $p < 1$  of detecting the interaction which is the same for all pairs of activities, time the benefit that accrues to the firm from exploiting this interaction, which for simplicity is normalized to 1. Hence,  $p$  is also the expected benefit from coordinating each pair of activities. The benefit of the company-wide interaction is  $s$ . The cost of hiring the middle manager is equal to  $F$  and includes both his salary and the search costs eventually incurred by the firm. If a middle manager is hired, she performs task BD only. Each task performed by owner-managers (i.e., detecting and exploiting pairwise and company-wide interactions) requires one unit of their time, which has an opportunity cost equal to  $q_t$ , given by the benefit that could be reaped by employing one more unit of their time in performing strategic tasks. We assume that  $q_t$  increases with firm’s age, for example, as a consequence of the increasing size and complexity of firm’s operations. We also assume that the expected benefit from coordinating the company-wide interaction, equal to  $p^4s$ , and from coordinating pairwise interactions, equal to  $p$ , are both greater than the corresponding opportunity cost  $q_t$ .

We compare a flat two-layer hierarchy in which owner-managers perform all tasks, with a three-layer hierarchy in which a middle manager is assigned responsibility for

task BD. The expected benefits of the two- and three-layer hierarchies, denoted as  $B^{2L}$  and  $B^{3L}$ , respectively, are as follows:

$$B_t^{2L} = 4(p - q_t) + (p^4s - q_t).$$

$$B_t^{3L} = p + 3(p - q_t) + p(p^3s - q_t) - F.$$

Thus, the expected net benefits  $\Delta_t$  of the addition of the middle manager layer is:

$$\Delta_t = (2 - p)q_t - F. \quad (1)$$

The benefits of recruiting a middle manager arise from (i) the saving  $q_t$  of the time that in absence of the middle manager, owner-managers would devote to the operating task BD, and (ii) the saving  $q_t$  of the time they devote to detection and exploitation of the company-wide interaction if no interaction is detected by the middle manager in task BD, which occurs with probability  $(1-p)$ .

### 2.3 INTRODUCING AGENCY CONSIDERATIONS

In accordance with the delegation literature, let us now assume that (i) candidate middle managers possess personal specific knowledge relevant to performing operating task BD, which owner-managers do not possess, and (ii) the objectives of middle managers diverge from those of owner-managers. Therefore, the delegation of task BD to a middle manager may engender benefits that could not be reaped with a two-layer hierarchy. However, it also engenders agency costs. Accordingly, we assume that if responsibility for task BD is assigned to a middle manager, (i) the likelihood of detecting and exploiting the interaction between activities B and D is  $\pi$ , with  $\pi > p$ , and (ii) because of agency costs, the benefit from exploiting interaction BD that accrues to the firm is  $1-\rho$ , with  $0 < 1-\rho < 1$ . Parameter  $\rho$  that captures agency costs, is inversely related to the ability of owner-managers to monitor middle managers' decisions and to realign their objectives with firm's objectives, for example, through the use of suitable incentive-based compensation schemes.

The expected benefit of a three-layer hierarchy is:

$$B_t^{3L} = \pi(1 - \rho) + 3(p - q_t) + \pi(p^3s - q_t) - F.$$

The expected net benefit of creating a middle-management level then becomes:

$$\Delta_t = (2 - \pi)q_t + (\pi - p)(1 + p^3s) - \pi\rho - F. \quad (2)$$

If  $\Delta_t \geq 0$ , the owner-manager will recruit a middle manager, switching to a three-layer corporate hierarchy.

### 2.4 THE EMPIRICAL MODEL

The model as specified above, abstracts from various real-life factors that, though they may be known with certainty to firms' owner-managers who face the decision of appointing a middle manager, cannot be incorporated into the model. These factors are introduced into the model through a stochastic error term  $\varepsilon$ . The adoption condition of a three-layer hierarchy as specified in equation (2) now becomes:  $\Delta_t + \varepsilon \geq 0$ . Assuming  $\varepsilon$  is distributed independent of  $\Delta_t$ , the probability of the adoption of a three layer hierarchy

in the small time interval  $\{t, t + dt\}$  for a firm that has not adopted it by time  $t$ , that is, the hazard rate  $h(t)$ , can be expressed in terms of our variables of interest as:

$$h_i(t) = \text{Prob} \{ \Delta_t + \varepsilon \geq 0 \} = J(q_t, \pi, \rho, F). \tag{3}$$

In particular, the variables on which we focus attention are: the opportunity cost  $q_t$  of the owner-managers' time; the information advantage of middle managers regarding task BD, captured by  $\pi$ ; the extent of agency costs, captured by  $\rho$ ; and the cost  $F$  the firm needs to incur to recruit a middle manager. From equation (2), we have that  $J_1 > 0$ ,  $J_2 > 0$ ,  $J_3 < 0$ , and  $J_4 < 0$ , because  $\Delta_t$  is a positive function of  $q_t$  and  $\pi$ , and a negative function of  $\rho$  and  $F$ :

$$\frac{\partial \Delta_t}{\partial q_t} = 2 - \pi > 0,$$

$$\frac{\partial \Delta_t}{\partial \pi} = (1 - \rho) + p^3s - q_t > 0, \text{ as } 1 - p > 0 \text{ and } p^3s > p^4s > q_t, \tag{4}$$

$$\frac{\partial \Delta_t}{\partial \rho} = -\pi < 0,$$

$$\frac{\partial \Delta_t}{\partial F} = -1.$$

In the following, we examine factors that influence the values of parameters  $q_t$ ,  $\pi$ ,  $\rho$ , and  $F$ , and therefore the likelihood of an entrepreneurial venture switching to a three-layer corporate hierarchy. The effect of these factors is synthesised in Table I, where we distinguish the characteristics of the entrepreneurial team, firm-specific, and industry-specific characteristics.

**2.4.1 THE OPPORTUNITY COST OF OWNER-MANAGERS' TIME ( $q_t$ )**

We expect the opportunity cost of owner-managers' time to be higher for owner-managers with higher human capital, as reflected by their education and work experience. For these individuals it is extremely profitable to devote time and attention to strategic decisions, while leaving responsibility for operating decisions to middle managers. Devoting time and attention to strategic decisions is also very profitable for owner-managers of firms that operate in an uncertain, rapidly changing business environment (Keren and Lehvari, 1989; Radner, 1993) or face tough competition (Meagher and Wait, 2008), as in these situations timely decision-making is fundamental.

Conversely, if the number of firm's owner-managers is larger, they will have more time to perform operating tasks. Similarly, if owner-managers use advanced reporting and decision support systems, for example, enterprise resource planning (ERP) software, to collect information, they can speed up the decision-making process. Under these circumstances,  $q_t$  is lower and there is less need to "protect" owner-managers from absorption in operating tasks. With all else equal, the switch to a three-layer corporate hierarchy will be less likely.<sup>9</sup>

9. As will be illustrated below, some of the factors considered here have multiple effects on parameters  $q_t$ ,  $\pi$ , and  $\rho$ . Therefore, the net effect of these factors on the appointment of a middle manager may be indeterminate because it is the result of the composition of opposed forces.

**TABLE I.**  
**THE DETERMINANTS OF THE CREATION OF A MIDDLE-MANAGEMENT LEVEL BY ENTREPRENEURIAL VENTURES: THEORETICAL PREDICTIONS**

Theoretical Backgrounds	Information-Processing	Decentralisation of Incentives		Labour Market Factors	Total effect
		Information advantage of middle managers $\pi$	Agency costs $\rho$		
Theoretical model parameters	Opportunity cost of owner-managers' time $q_t$				
<b>Variables</b>					
<i>Entrepreneurial team</i>					
Owner-managers' human capital	+				+
Heterogeneity of owner-managers' functional competencies		-			-
Owner-managers' management experience			+		+
Owner-managers' entrepreneurial experience			+		+
Number of owner-managers	-		+		?
<i>Firm-specific</i>					
Firm age				+	+
Use of advanced reporting and decision support system (ERP)	-		+		?
Firms' awards				+	+
VC investment				+	+
<i>Industry-specific</i>					
Appropriability			+		+
Market competition	+				+
Business uncertainty	+	+	-		?
Uncertainty in firm quality				-	-

Note: +: positive expected effect on the likelihood of creating a middle-management level; -: negative expected effect on the likelihood of creating a middle-management level; ?: uncertain predictions.

#### 2.4.2 THE INFORMATION ADVANTAGE OF MIDDLE MANAGERS IN OPERATING TASKS ( $\pi$ )

There are two situations where the specific knowledge possessed by middle managers is especially valuable for owner-managers. First, if the business environment is highly uncertain and unexpected events deeply influence the outcome of different decisions, it is more difficult to make the "right" decision.<sup>10</sup> Hence, the information advantage that individuals with specific operational expertise (e.g., a seasoned salesman) enjoy over owner-managers is larger, and so the benefits of assigning to these individuals

10. In the delegation literature, the terms "volatility" and "technological uncertainty" are used to distinguish this type of uncertainty from uncertainty that influences measured performance but does not affect decisions. For this latter type of uncertainty, scholars generally use the term "noise". See Rantakari (2008b).

decision authority over these operations and raising them to the managerial ranks are greater (Zabojnik, 1996; Prendergast, 2002; Baker and Jorgensen, 2003; Raith, 2008). Second, the likelihood of middle managers enjoying an information advantage over owner-managers in a particular operational area is greater, if the scope of the functional expertise of the team of owner-managers is narrower (e.g., if all owner-managers are technicians and lack commercial competencies).

#### 2.4.3 THE EXTENT OF AGENCY COSTS ( $\rho$ )

As was said earlier, the agency costs engendered by appointing a middle manager and delegating her authority over (some) operating decisions can be alleviated through effective monitoring of middle manager's decisions and use of high-powered incentives that link her salary to performance. The monitoring ability of owner-managers is likely to increase with the size of the team of owner-managers and use of ERP systems. Because of learning by doing, it is also likely to be greater if owner-managers are serial entrepreneurs or had managerial responsibility in their former job. As to high-powered incentives, they will be more expensive to use if the business environment is more uncertain and the available performance measures are noisier (e.g., Prendergast, 1999).<sup>11</sup>

Lastly, agency costs are likely to be large if the source of the competitive advantage of an entrepreneurial venture lies in the possession of innovative technologies, as is usual in high-tech industries, and the appropriability regime (Levin et al., 1987) is weak. Under these circumstances the middle manager, while performing her duties, is likely to be able to absorb firm's knowledge and then exploit it to her personal benefit. This may erode the very source of the firm's competitive advantage.<sup>12</sup>

#### 2.4.4 THE COST OF RECRUITING A MIDDLE MANAGER ( $F$ )

If owner-managers appoint a firm's employee as middle manager, the only cost the firm incurs is the salary increase of this individual. Conversely, if there are no suitable internal candidates for the middle manager position, there are two types of additional costs. First, the firm will incur transaction costs in searching in the managerial labor market for a suitable candidate. Second, provided that one or more suitable candidates have been found, the firm may be forced to pay a "lemon premium" (Akerlof, 1970) because of the existence of information asymmetries regarding firm's quality and future business prospects between owner-managers and would-be middle managers. Both these types of costs are likely to be smaller for venture capital (VC)-backed entrepreneurial ventures. On the one hand, these firms can rely on the social networks of their VC investors to find candidate middle managers (Gorman and Sahlman, 1989; Hellmann and Puri, 2002). On the other hand, we expect these individuals to be more prone to accept an employment offer made by a VC-backed firm due to the "certification effect" of VC investments (Megginson and Weiss, 1991). A similar certification effect may be at play when a firm

11. Whether environmental uncertainty increases or decreases the likelihood of creating a middle-management level depends on the *type* of uncertainty. Volatility magnifies the information advantage of would-be middle managers and makes timely decision-making more crucial. Hence it makes the creation of a three-layer hierarchy more likely. Conversely, noise renders it more costly to tie middle managers' compensation to firm performance and thus has an opposite effect. Empirical studies on the impact of environmental uncertainty on delegation of decision rights provide mixed evidence: some studies show that the former effect prevails (e.g., Foss and Laursen 2005), others find the opposite (e.g., Wulf 2007), and in still other studies, the two effects neutralize each other (see Prendergast 2002 for a review).

12. For instance, to efficiently market the applications of a novel technology and to convince potential customers of the technology's value, a newly appointed sales manager must be made aware of sensitive information about this technology. This creates the potential for technological leakages that may be very detrimental to a firm's destiny if the middle manager is then recruited by a competitor or starts her own enterprise.

can boast objective technological achievements like a patent grant (Hsu and Ziedonis, 2007) or the award of research grants from a reputable governmental body (Lerner, 1999). Conversely, the extent of the information asymmetries is likely to be greater for younger ventures that lack a track record and for firms that operate in industries in which evaluating firms' quality and future business prospects is especially difficult.

### 3. DATA

#### 3.1 THE SAMPLE

In this paper, we consider a sample composed of 524 Italian high-tech entrepreneurial ventures. Sample firms were established in 1980 or later, were owner-managed at their inception and remained independent up to 1/1/2004. They operate in the following high-tech sectors in manufacturing and services: computers; electronic components; telecommunication equipment; optical, medical and electronic instruments; avionics; biotechnology; pharmaceuticals; advanced materials; robotics; process automation equipment; software; the Internet; and telecommunication services. For us to exclusively consider entrepreneurial ventures operating in high-tech industries presents three main advantages. First, high-tech entrepreneurial ventures provide a controlled setting to test the predictions of different economic theories. The fact that there is limited cross-sector heterogeneity in the type of activity performed by sample firms limits confounding effects. Second, the generation and efficient use of knowledge is a crucial source of competitive advantage for these firms. Because the knowledge possessed by both firms' owner-managers and candidate middle managers plays a key role in the arguments illustrated in the previous section, these firms provide an ideal testing ground for these theories' predictions. They also allow one to assess the deterrence effects of adverse selection problems in the managerial labour market and the role of signals of firms' quality in alleviating these problems. Third, organizational depth is observed for all sample firms from their inception up to the time when a middle-management layer is added to the corporate hierarchy or up to 2003 if it is not. As a result, the dependent variable (i.e., the hazard rate of creating the first middle-management position) is defined unambiguously for all sample firms and the effects of path-dependency are less disturbing than in previous studies that focused on large firms.

The sample was extracted from the Research on Entrepreneurship in Advanced Technologies (RITA) database developed at Politecnico di Milano (for a detailed description, see the on-line appendix).<sup>13</sup> RITA provides information on 1,974 Italian high-tech entrepreneurial ventures that comply with the above mentioned criteria related to foundation age, independence and the sector of operations. In the absence of reliable data on this type of firms provided by official national statistics (see again the on-line appendix), the RITA database is the most comprehensive information source presently available on Italian high-tech entrepreneurial ventures and furnishes an accurate representation of the population of existing Italian entrepreneurial growth-oriented ventures in high-tech sectors at the beginning of 2004.

The data contained in the RITA database were collected from two types of sources. The yearly data on patent activity, participation in European Union (EU)-funded R&D projects (like the ones promoted by Framework Programs or Eureka), and

13. In the on-line appendix (see Supporting Information), we make available a detailed description of the RITA directory and three additional tables (A1, A2 and A3, see *infra*).

accounting data (including firm size and growth) were obtained from secondary sources: the databases of the patent offices that are accessed through the Esp@ce.net search engine, the CORDIS database developed by the European Commission, and the AIDA (the Italian fine-grained version of the Amadeus-Bureau Van Dijk database) and CERVED commercial databases, respectively. The second source of information consists of a series of national surveys that were administered in the first two quarters of 2000, 2002, and 2004. The surveys were based on a questionnaire that was sent to the contact person of target firms (i.e., one of firm's owner-managers) either by fax or by e-mail. The first section of the questionnaire provides detailed information on the human capital characteristics of firms' founders. The second section includes further questions concerning the characteristics of firms and, notably, their organization (see below for more details). The third section includes a series of questions about the technological and business environment in which firms operate. Answers to the questions were checked for internal coherence by trained research assistants and were compared with information published in firms' annual reports, on web sites and in the press. Data on VC investments in sample firms were also cross-checked with information from secondary information sources (e.g., the VentureXpert database). In several cases, phone or face-to-face follow-up interviews were made with firms' owner-managers. This final step allowed to collect missing data and ensured that the data were reliable.

Regarding firm organization, the questionnaire asked firms' owner-managers to indicate whether the corporate hierarchy of the firm had ever included one or more middle-management layers. And 59 firms answered "yes" to this question. All these firms were contacted with the purpose of arranging a phone or face-to-face interview with an owner-manager. And 39 owner-managers were interviewed, while the owner-managers of 20 firms declined to be interviewed or to provide the data we wanted to collect. These interviews allowed us to gather data on the date of appointment of the first salaried manager, and other characteristics of the position that was created (notably, type of task-technological, commercial, administrative, or general management, type of compensation scheme-fixed or incentive based compensation scheme, and whether the appointed manager was promoted from the internal workforce or was hired from the labour market). The creation of a middle-management position is a key milestone in the life of a high-tech entrepreneurial venture because it generally involves a radical reorganization of management practices and responsibilities. Moreover, in Italy, salaried managers enjoy a special status recognised by law. They belong to a specific union different from that of other workers, and their employment contract is subject to specific national regulation. Therefore, appointing a salaried middle-manager is an important decision for a small firm. Accordingly, 37 out of the 39 interviewed owner-managers were able to indicate the year in which this organizational change occurred. Although we cannot exclude that there is a retrospective bias in our data, we are quite confident that all necessary measures were taken to make this bias as limited as possible.

The sample used in the present work consists of the RITA firms that were in operations at the beginning of 2004 and participated in the 2004 survey (and eventually participated also in the 2000 and/or 2002 surveys). Two  $\chi^2$  tests show that there are no statistically significant differences between the distribution of the sample firms across industries and geographic areas and the corresponding distribution of the population of 1,974 RITA firms from which the sample was drawn ( $\chi^2(4) = 2.29$  and  $\chi^2(3) = 3.90$ , respectively). The sample is large and quite heterogeneous. Moreover, data on sample firms are very informative and reliable. However, as is common in survey-based studies,

the sample suffers from survivorship bias because only firms that survived through 1/1/2004 are included in the sample. In principle, attrition may generate a sample selection bias in our estimates. On one hand, the failure rates of high-tech entrepreneurial ventures are likely to decrease with managerial professionalization because these firms allegedly benefit from a greater endowment of skilled human resources. On the other hand, an opposite bias may also exist because firms with greater managerial resources may be more likely to become the target of an acquisition. As a matter of fact, it is fair to admit that we are not able to rigorously control for this selection bias; nonetheless, we are able to provide partial evidence that the influence of a selection bias on the results should be fairly limited (see Section 4.3).

### **3.2 THE MANAGERIAL PROFESSIONALISATION OF ITALIAN HIGH-TECH ENTREPRENEURIAL VENTURES**

In this section, we use information on the 524 sample firms to provide a preliminary description of the creation of a middle-management level by Italian high-tech entrepreneurial ventures. Only 59 of these firms appointed one or more middle managers during their life (11.3% of the sample). This figure suggests that in Italy, there are serious obstacles preventing the managerial professionalisation of high-tech entrepreneurial ventures. Differences in the managerial professionalisation rate across geographic areas are fairly limited, whereas there are considerable differences across industries. In particular, the appointment of a middle manager appears to be less likely in the robotics and automation equipment sector (6.7%), while software (14.1%) shows the greatest share of firms creating a middle-management layer (see Table AI in the on-line appendix). We are also able to distinguish firms based on whether the first middle manager was an internal upgrade or an external hire, the type of compensations scheme that was offered to the newly appointed manager and her task. The data on these issues are presented in Table AII and are available only for 39 firms, so they could not be used in the econometric analysis. In appointing their first middle manager, 51.3% of firms resorted to the managerial labour market, while in 48.7% of cases, the middle manager came from the internal workforce. The percentage of managers with incentive-based compensation schemes (e.g., stocks, stock options, bonuses tied to individual or firm-specific targets) is 56.4%. The great majority of sample firms introduced their first middle manager in a specific functional area, that is, 76.9%, where the production/technology area accounts for the largest share (41.0%). Indeed, the creation of a chief operating officer position is relatively rare (23.1%). When it happens, in two thirds of cases, the individual chosen for this job is promoted from the internal ranks.

In Figure 1, we plot the estimated (smoothed) hazard rate, which is the conditional probability of creating a middle-management level after  $t$  years since a firm was founded given that this has not happened up to  $t$ ; we computed these figures using the Nelson-Aalen estimator (see Nelson, 1972; Aalen, 1978). The hazard rate (almost) monotonically increases with firm age, reaching a peak that corresponds with a firm age equal to 20 years; then it slightly decreases. Note, however, that this estimator does not control for other covariates that may influence the hazard rate. In particular, because firm size generally grows over time, the increase in the hazard rate with firm age might simply indicate that larger firms are more likely to create middle-manager positions. To disentangle these different effects, a more structured analysis highlighting the effects of covariates is in order.

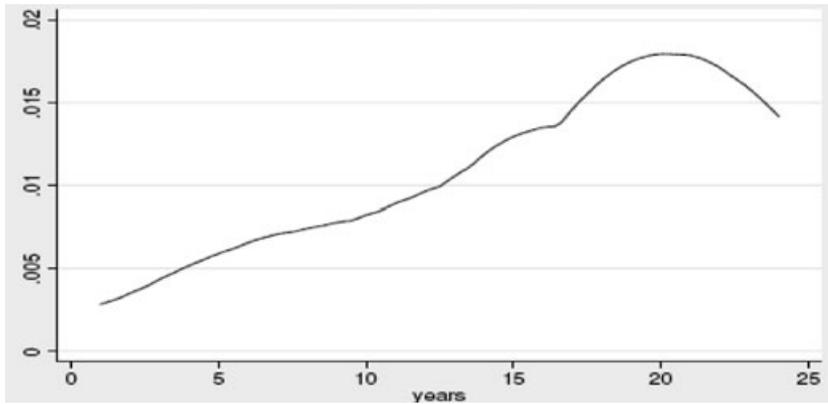


FIGURE 1. ESTIMATES OF THE NON-PARAMETRIC HAZARD FUNCTION OF THE CREATION OF A MIDDLE-MANAGEMENT LEVEL

Note: The Estimated Hazard is Calculated As a Kernel Smooth of the Estimated Hazard Contribution. Epanechnikov Kernel Functions and Optimality Criterion Used for Choice of Bandwidth.

#### 4. THE ECONOMETRIC ANALYSIS

##### 4.1 THE SPECIFICATION OF THE ECONOMETRIC MODEL

We investigate the determinants of the creation of a middle-management level through the estimate of different econometric models. More specifically, we estimate models relating the observed period (measured in years) needed for firms to create the first middle-management position to variables that reflect entrepreneur-, firm- and industry-specific characteristics and other controls. The maximum sample size available for this multivariate analysis shrinks from 524 to 496 firms because of missing data. Availability of employment data limits our observation period to the time frame 1994–2003. As 6 high-tech entrepreneurial ventures appointed their first middle-manager before 1994, they were excluded from the estimates. Moreover, for 22 firms we do not know the year when the middle-management level was created.<sup>14</sup> Lastly, information on the prior entrepreneurial experience of individuals starting the venture and the firm's adoption of advanced reporting and decision support systems is available only for a subsample of firms (for 437 and 373 firms, respectively). Therefore, models including the corresponding variables are estimated for a reduced sample.

The basic tools for modelling duration data, given the right-censored nature of the sample (i.e., the presence within the sample of firms that did not introduce a middle-management position), are duration or hazard models (see Keifer, 1988; Cameron and Trivedi, 2005). The visual inspection of the nonparametric hazard function estimates (see again Figure 1) and the fact that only 43 sample firms were established before 1984 (i.e., were more than 20 years old at survey date), suggest that the hazard rate may be reasonably proxied as monotonically increasing with firm age. Then, as is frequent in this type of literature (e.g., Colombo and Delmastro, 2002), we choose to model

14. We checked the influence of the inclusion of these latter firms on the econometric results by means of Monte Carlo simulations (see Section 4.6). Moreover, we rerun all the estimates after excluding all firms (184 firms) that were established before 1994. Results that are not reported in the paper for the sake of synthesis, remain pretty similar. They are available from the authors upon request.

the hazard function via a Weibull distribution.<sup>15</sup> Therefore, the hazard rate of (3) and the corresponding survival function are given by  $h_i(t) = p\lambda_{it} t^{p-1}$  and  $S_i(t) = \exp(-\lambda_{it}t^p)$ , where  $\lambda_{it} = \exp(\beta'x_{it})$ ,  $x_{it}$  is the set of independent variables,  $\beta$  is its associated parameter vector and  $p$  is the parameter that rules duration dependence: when  $p$  equals one, there is no duration dependence, and when  $p$  is greater (smaller) than one, there is positive (negative) duration dependence.

## 4.2 THE EXPLANATORY VARIABLES

We consider three groups of variables that, in accordance with the theory developed in Section 2, are likely to influence the likelihood of creating a middle-management level (see again Table I): (i) the characteristics of the entrepreneurial team, (ii) firm-specific characteristics, and (iii) industry-specific characteristics of the business and technological environment in which the firms operate. Definitions of variables are provided in Table II, while in Table III we report descriptive statistics for the observation period (1994–2003). Time-varying covariates (in levels) are lagged so to lower endogeneity worries (with limited loss of observations).

### 4.2.1 ENTREPRENEURIAL TEAM VARIABLES

In this work, absent time-varying data on the characteristics of the owner-managers of sample firms, we proxy these characteristics using those of the founding team. In so doing, we make the implicit assumption, quite common in the entrepreneurship literature, that founders have a durable imprint on the firms they created.<sup>16</sup>

The human capital of founders is measured by years of university education in economic and managerial disciplines (*Eco-Education*) and technical and scientific disciplines (*Tech-education*), as well as by years of work experience prior to the establishment of the firm (*Workexp*). These variables are averaged across founders. We predict a positive coefficient for these variables because the opportunity cost of owner-managers' time is likely to increase with their skill level proxied by human capital. *Hetero-work* reflects the functional heterogeneity of the competencies of the founders as they result from their work experience prior to the firm's founding. More precisely, this variable is an Herfindahl-type index that equals 0 if all founders have prior work experience in the same functional area and that increases with the diversity of this work experience. We predict that if the team of owner-managers is more heterogeneous, it is less likely that a would-be middle manager possesses valuable specific knowledge in areas where owner-managers lack competencies. In turn, this makes the creation of a middle-management position less likely.

15. Note that the alternative semi-parametric approach (e.g., Cox 1972) yields similar results to those presented here. We also produced estimates choosing other parametric hazard functions (e.g. Gompertz, exponential, log logistic, log normal). Results are consistent across different choices and do not alter the basic findings of our analysis. They are available from the authors upon request.

16. On the "founding imprinting" effect, see among many others Stinchcombe (1965), Boeker (1988), Barringer et al. (2005), Colombo and Grilli (2005), Beckman and Burton (2008). In particular, Baron et al. (1996) find that founders' organizational model influences the hazard rate of the creation of the first human-resource manager position in Silicon Valley entrepreneurial ventures. Baron et al. (1999a) show that founders have an enduring effect on the managerial-administrative intensity of these firms (see also Baron et al. 1999b). Even though we do not know the composition over time of the team of owner-managers, we do know whether there was any change in owner-manager teams during firm's life. In Section 4.6, we will exclude from the estimates all firms for which we have recorded a change in the composition of the owner-manager team. This will provide a robustness check of the reliability of using founders' characteristics as a proxy of the characteristics of owner-managers.

**TABLE II.**  
**DEFINITION OF EXPLANATORY VARIABLES**

Variable	Description
<i>Eco-education</i>	Average number of years of economic and/or managerial university level education of founders.
<i>Tech-education</i>	Average number of years of scientific and/or technical university level education of founders.
<i>Workexp</i>	Average number of years of work experience of founders before firm's inception.
<i>Hetero-work</i>	Herfindhal-type index given by: $1 - \sum_{i=1}^5 (Years_i)^2$ . We consider 5 categories of founders' work experience: technical experience in the same sector of the start-up; technical experience in other sectors; commercial experience in the same sector of the start-up; commercial experience in other sectors; other professional experience. $Years_i$ represents the share of the years of work experience of founders in category $i$ out of their total work experience. Greater values of the index indicate greater heterogeneity of founders' work experience.
<i>DManager</i>	One for firms with one or more founders with a prior management position in another firm.
<i>DEntrepreneur</i>	One for firms with one or more founders with a previous entrepreneurial experience.
<i>NFounders</i>	Number of founders.
<i>ERP<sub>t-1</sub></i>	One for firms that use advanced reporting and decision support systems at $t - 1$ .
<i>Patent<sub>t-1</sub></i>	One for firms that up to $t - 1$ have been awarded one or more patents.
<i>EUProject<sub>t-1</sub></i>	One for firms that up to $t - 1$ have been involved in one or more collaborative research projects funded by the European Union (EU).
<i>IVC<sub>t-1</sub></i>	One for firms that up to $t - 1$ have obtained venture capital financing from an independent financial intermediary.
<i>CVC<sub>t-1</sub></i>	One for firms that up to $t - 1$ have obtained corporate venture capital financing.
<i>Appropriability</i>	Industry average of the mean scores assigned by RITA firms to the importance of patents and IPR protection, secrecy, product complexity, lead-time, learning curves and strategic barriers to entry (brand, customer care, control of distribution channels) to appropriate the benefits from innovations in their industry on a Likert scale from 1 to 6. Greater values indicate tighter appropriability.
<i>Price competition</i>	Industry average of the standardized scores assigned by RITA firms to the extent of price competition in their industry on a Likert scale from 1 to 6. Greater values indicate tougher competition.
<i>Market fragmentation</i>	Share of RITA firms that indicated that in their industry, products and services typically are custom designed according to specific user requirements.
<i>Business uncertainty<sub>t-1</sub></i>	Absolute value of the yearly residual obtained from a first-order autoregressive model AR(1) estimated on the series (years available over the period 1980–2005) of the gross output value in current price of each industry (Source: OECD-STAN database for Structural Analysis, ed. 2008).
<i>Uncertainty in firm quality</i>	Industry average of the normalised standard error of the market price of newly listed firms in the 50 days following the IPO. The data are calculated on 482 IPOs that occurred between 1996 and 2001 in five new European stock markets (Neuer Markt, Nuovo Mercato, Nouveau Marché, Euro NM, Nmax).
<i>Size<sub>t-1</sub></i>	Number of firm's salaried employees at $t - 1$ (in full time equivalent).
<i>Growth<sub>t</sub></i>	Firm yearly growth rate of employment at $t$ .
<i>Education of local workforce</i>	Weighted average of employees' level of education at NUTS 3 level (average is weighted on the number of employees). Employees' level of education is measured on a scale from 1 (low level of education) to 6 (high level of education) (Source: ISTAT Italian census, 2001).

**TABLE III.**  
**DESCRIPTIVE STATISTICS OF EXPLANATORY VARIABLES**

Variable	Mean	S.D.	Min	Max
<i>Eco-education</i>	0.266	0.817	0	4.5
<i>Tech-education</i>	1.821	2.182	0	8
<i>Workexp</i>	11.210	7.316	0	36
<i>Hetero-work</i>	0.198	0.252	0	0.750
<i>DManager</i>	0.247	0.431	0	1
<i>DEntrepreneur</i>	0.396	0.489	0	1
<i>NFounders</i>	2.820	1.883	1	21
<i>ERP<sub>t-1</sub></i>	0.233	0.423	0	1
<i>Patent<sub>t-1</sub></i>	0.043	0.205	0	1
<i>EUProject<sub>t-1</sub></i>	0.035	0.184	0	1
<i>IVC<sub>t-1</sub></i>	0.030	0.170	0	1
<i>CVCT<sub>t-1</sub></i>	0.044	0.205	0	1
<i>Appropriability</i>	3.990	0.150	3.790	4.400
<i>Price competition</i>	-0.005	0.200	-0.683	0.445
<i>Market fragmentation</i>	0.715	0.074	0.500	0.860
<i>Business uncertainty<sub>t-1</sub></i>	0.075	0.117	0.001	0.671
<i>Uncertainty in firm quality</i>	0.035	0.003	0.030	0.039
<i>Size<sub>t-1</sub></i>	10.387	16.874	0	370
<i>Growth<sub>t</sub></i>	0.213	0.687	-0.980	16
<i>Education of local workforce</i>	3.692	0.133	3.423	3.964

Note: Number of observations is 2,981, except for the variables *ERP<sub>t-1</sub>* (no. 2258) and *DEntrepreneur* (no. 2651).

The managerial and entrepreneurial competencies of owner-managers are captured by *DManager* and *DEntrepreneur*, respectively. These two dummy variables equal unity if the team of founders includes one or more individuals with prior managerial experience at other firms and prior entrepreneurial experience (i.e., a “serial entrepreneur”). We predict positive coefficients for these variables because previous experience in “bossing” increases the monitoring ability of owner-managers and lower agency costs in the creation of a middle-management position.

Lastly, *NFounders* is the number of owner-managers at the firm’s inception. The effect of this variable on the hazard rate of the creation of a middle-management layer is uncertain: with a greater number of owner-managers the opportunity cost of their time is lower, but agency costs are lower too because owner-managers have more time to closely monitor middle managers.

#### 4.2.2 FIRM-SPECIFIC VARIABLES

*ERP* captures the adoption of ERP systems by firms. The effect of this variable on the creation of a middle manager layer is uncertain. Use of these advanced technologies decreases the opportunity costs of owner-managers’ time, as it allows them to process information and make decisions more effectively. However, it also helps in monitoring middle managers’ decisions, thereby reducing agency costs.

*Patent* equals one if the focal firm was awarded one or more patents. *EUproject* similarly equals one if the firm participated in one or more EU-funded R&D projects. *IVC* and *CVC* are equal to one for firms that obtained VC financing from an independent VC firm and a corporate VC investor, respectively. We predict positive coefficients for these variables as they allegedly lower the cost of recruiting a middle manager.

#### 4.2.3 INDUSTRY-SPECIFIC VARIABLES

Industry-specific variables are aimed at capturing the characteristics of firms' technological and business environment. *Appropriability* reflects the tightness of the appropriability regime in firms' industry. It was computed as follows. Owner-managers of RITA firms were asked to use a Likert scale from one to six to rate the importance in their industry of six strategies intended to appropriate the benefits of new or improved products, services and processes (for a similar approach, see Levin et al., 1987). These strategies are patent and copyright protection, trade secrecy, product complexity, lead-time generating a first-mover advantage, learning curves, and strategic barriers to entry (e.g., brand, customer care, and control of distribution channels). First, for each firm we averaged the six scores. Then, for each industry we calculated the average of the mean score attributed to these six mechanisms by the firms that operate in that industry. We expect a positive impact of this variable on the creation of a middle-management level because with a tight appropriability regime, the appropriability hazards and the associated agency costs arising from the appointment of a middle manager are reduced.

Then we created two proxies for market competition. Again, RITA firms' owner-managers were asked to use a Likert scale from one to six to assess the extent of price competition in their industry. We standardized these values. *Price competition* measures the industry average of these standardized scores. *Market fragmentation* measures the share of RITA firms out of those that operate in a given industry that indicated that in this industry, products and services typically are custom designed according to specific user requirements. It is an inverse proxy of the extent of competition. With tough competition, the opportunity cost of owner-managers' time is greater. Therefore, we predict a positive coefficient for *Price competition* and a negative one for *Market fragmentation*. We also introduced into the model specification a variable reflecting uncertainty in the business environment. We considered the series of gross output value in current price over the period 1980–2005 of each three-digit NACE-CLIO industry in which RITA firms operated (source: OECD). For each industry *Business uncertainty* is computed as the absolute value of the yearly residual obtained from a first-order autoregressive model AR(1) estimated on these series. Larger residuals (in absolute value) denote greater uncertainty in the industry because the past value of the gross industry output is of limited help in predicting the future value one step ahead. Greater environmental uncertainty increases the opportunity costs of owner-managers' time as it renders timely decision-making more important. It also magnifies the information advantage allegedly possessed by would-be middle managers. However, with greater uncertainty, indicators of firm performance are noisier, and the use of high-powered incentives to compensate middle managers is more expensive. As a result of these opposed forces, the net effect of this variable on the creation of a middle-management level is uncertain.

Uncertainty in the quality of high-tech entrepreneurial ventures increases the cost of hiring a middle manager, as it renders adverse selection problems more severe. To create a proxy for this variable, we used the database on European initial public offerings (IPO) that was jointly developed by Politecnico di Milano and Tilburg University. This database includes data on 482 IPOs that occurred between 1996 and 2001 in five European new stock markets (Neuer Markt, Nuovo Mercato, Nouveau Marché, Euro NM, Nmax).<sup>17</sup> *Uncertainty in firm quality* measures the industry average of the normalised standard deviation of the market price of newly listed firms in the 50 days following the IPO.

17. Data on IPOs have been collected primarily through IPO brochures and company websites, while data on market prices have been obtained from the Datastream database and the websites of the above-cited new markets. For further details, see Giudici and Roosenboom (2002).

#### 4.2.4 CONTROL VARIABLES FOR “SIZE” EFFECTS

The likelihood of appointing a middle manager is likely to be influenced by the size of firms' operations. The information processing stream argues that if a firm grows larger, the firms' owner-managers will increasingly suffer from information overload problems that will make decision-making inefficient.<sup>18</sup> Similarly, the decentralization of incentive stream contends that the increase in the span of control associated with an increase in firm size makes it more difficult for owner-managers to closely monitor the behaviour of line workers, thereby rendering the firm less productive. Both problems can be alleviated by appointing a middle manager. In accordance with both these theoretical arguments and previous empirical evidence (see e.g., Colombo and Delmastro, 2008, chapter 3), we expect the likelihood of the creation of a middle-management level to increase with the variables *Size* and *Growth* which measure firms' number of salaried employees (in full-time equivalent) and the yearly growth rate of employment, respectively.

Finally, we also add a control variable related to the location of the entrepreneurial venture and aiming at proxying the size of the supply in the local managerial labour market. In particular, we introduced into the model a measure of the level of education of the workforce in the provinces (NUTS 3 level) where firms are located (*Education of local workforce*; source: ISTAT).<sup>19</sup>

#### 4.3 CORRECTION FOR A POTENTIAL SURVIVORSHIP BIAS

The use of survey information necessarily implies a potential survivorship bias in the data that may interfere with the investigated relationship. To examine the extent of this bias, we focused our attention on the RITA 2000 sample. This sample, composed of 401 firms, was selected according to the same criteria and strategy that were used for the RITA 2004 sample (see Colombo et al., 2004). Of these firms, 101 exited (by closure or merger and acquisition) the sample in the 2000–2003 period. In the sub-sample of surviving firms, the fraction of firms with three or more hierarchical layers was only slightly higher than in the sub-sample of exited firms (15.0% and 10.9%, respectively); a  $\chi^2$  test showed that the difference between the two sub-samples was not statistically significant at any conventional level ( $\chi^2(1) = 1.06$ ).

In addition, to further check to what extent our results could be affected by a possible survivorship bias, we mimicked a Heckman-like two-step procedure in order to control directly for a potential selection bias brought into data by sample attrition. It is worth remarking here the tentative nature of this test, given our data constraints and the questionable applicability of the method in the context of a nonlinear second-stage (e.g., Greene, 2005).<sup>20</sup> In particular, based on the RITA 2000 sample, we estimated a probit model on firm exit in the 2000–2003 period conditional on survival up to the

18. This argument dates back to Max Weber's seminal study of bureaucratic organizations (see Weber 1946).

19. The market we are analyzing is intrinsically opaque, being mostly made up by personal contacts and private negotiations. Thus, if from one side the variable can only imperfectly proxy the supply of managers at local level, from the other side, it does not incorporate market outcome realizations (e.g. number of managers in the area), and therefore it is truly exogenous with respect to our dependent variable.

20. The incapacity to properly control for a potential survivorship bias in our data represents a limitation of the present study. However note that, being similar in spirit to a classical test for selection bias in linear panel data models (Wooldridge 1995; see also Baltagi 2003, p. 223), the procedure we followed in our non-linear Weibull survival model mirrors the one of Eckhardt et al. (2006). A similar procedure in duration analysis is also present in Dencker et al. (2009) while a comparable test (for detecting a non-response bias) in a non-linear second-stage model is performed in Lanoie et al. (2011, p. 813). We thank the anonymous co-editor and referee for enabling us to clarify the point.

end of 1999; the dependent variable in this model is the hazard rate of exit of sample firms in the 2000–2003 period. The independent variables of this sample selection model included founders' human capital variables (i.e., years of work experience prior to firms' foundation and years of technical-scientific and economic-managerial university-level education), a dummy variable indicating the presence in the founding team of one or more individuals with prior managerial experience, firm size and age in 1999, and industry controls. We also inserted a composite index measuring the level of infrastructure and resources development in the province (NUTS 3 level) of firm's location.<sup>21</sup> The variable is found to significantly affect firms' survival dynamics ( $p$ -value = 0.0291), but it does not exert any direct influence on the hazard rate of creation of a middle-management level and so it acts as a viable exclusion restriction with respect to the main model. We then used the estimated coefficients of this model to compute  $IMR_{it}$ , the inverse Mills ratio of exit at age  $t$ , for each of the firms included in the sample under consideration in the present work. This time-varying ratio was then inserted as a control for survivorship bias in the main equation. This additional variable is intended to control for the unobserved heterogeneity that affects both a firm's probability of being sampled in 2004 and the likelihood of the firm's introducing a middle-management level into its organization. The statistical insignificance of its coefficient would (cautiously) suggest the absence of an important survivorship bias in the econometric estimates.

#### 4.4 ECONOMETRIC RESULTS

Table IV reports the estimation results of the survival data analysis model aimed at investigating the determinants of the addition of a middle-management level into the corporate hierarchy of a owner-managed two-layer high-tech entrepreneurial venture.<sup>22</sup>

Let us first consider the influence that entrepreneurial team variables exert on the creation of a middle-management layer. First, in line with the information processing stream and the knowledge hierarchy hypothesis, variables reflecting the human capital of entrepreneurs generally have a positive effect on the hazard rate. However, only *Eco-education* is significant (at 1%). Second, our findings suggest that contrary to expectations based on the decentralization of incentive stream, the introduction of a middle-management layer is more likely when founding teams are more heterogeneous, as is apparent from the positive coefficient of *Hetero-work*, which is significant at conventional confidence levels. Filling owner-managers' competencies gap does not prove to be a key driver of the creation of a middle-management position. Third, *DEntrepreneur* exhibits a positive, (weakly) significant coefficient in Model (2), in accordance with our prediction that the presence of a serial entrepreneur in the founding team reduces the agency costs generated by the appointment of a middle manager. Conversely, the previous managerial experience gained by founders, captured by *DManager*, does not have

21. The covariate provided by the National Association of Italian Companies (Centro Studi Confindustria) is calculated as the average of a series of indexes: per capita value added, share of manufacturing out of total value added, employment index, per capita bank deposits, automobile-population ratio, and consumption of electric power per head.

22. The results here presented as those that refer to robustness checks (see Section 4.6) indicate that the coefficient of the inverse Mills ratio is never statistically significant, suggesting the absence of an important survivorship bias. We also checked whether and to what extent the two-step nature of the correction for the potential survivorship bias affected the correctness of standard errors (Wooldridge 2002). Because differences in the variance-covariance matrix of the estimates with and without the *IMR* correction variable are always negligible, we prefer for the sake of synthesis to present only the most complete model specification including this correction variable.

**TABLE IV.**  
**THE DETERMINANTS OF THE CREATION OF A MIDDLE-MANAGEMENT**  
**LEVEL: THE WEIBULL SURVIVAL DATA ANALYSIS**

		Model 1		Model 2		Model 3	
$a_0$	Constant	29.981	(19.473)	41.028	(21.039)*	22.714	(23.950)
$a_1$	Eco-education	0.609	(0.232)***	0.909	(0.271)***	0.759	(0.290)***
$a_2$	Tech-education	0.022	(0.124)	0.097	(0.148)	0.111	(0.139)
$a_3$	Workexp	0.069	(0.051)	0.062	(0.050)	0.063	(0.055)
$a_4$	Hetero-work	1.813	(0.995)*	2.165	(1.180)*	2.430	(1.101)**
$a_5$	DManager	-0.231	(0.444)	-0.525	(0.546)	-0.770	(0.582)
$a_6$	DEntrepreneur	-	-	0.873	(0.482)*	-	-
$a_7$	NFounders	-0.242	(0.223)	-0.140	(0.215)	-0.264	(0.268)
$a_8$	ERP <sub>t-1</sub>	-	-	-	-	0.686	(0.468)
$a_9$	Patent <sub>t-1</sub>	0.035	(0.774)	-0.866	(1.173)	0.073	(0.703)
$a_{10}$	EUproject <sub>t-1</sub>	1.147	(0.624)*	0.873	(0.681)	0.890	(0.522)*
$a_{11}$	IVC <sub>t-1</sub>	1.701	(0.764)**	1.315	(0.945)	0.977	(1.066)
$a_{12}$	CVC <sub>t-1</sub>	-0.895	(0.990)	-0.930	(1.066)	-1.033	(1.177)
$a_{13}$	Appropriability	-5.238	(2.047)**	-4.993	(2.190)**	-2.996	(2.131)
$a_{14}$	Price competition	3.733	(2.210)*	1.751	(2.022)	2.635	(1.803)
$a_{15}$	Market fragmentation	-11.363	(4.426)***	-10.563	(4.413)**	-8.751	(3.882)**
$a_{16}$	Business uncertainty <sub>t-1</sub>	2.240	(1.216)*	3.073	(1.219)**	2.304	(1.113)**
$a_{17}$	Uncertainty in firm quality	-168.164	(167.024)	-364.964	(148.539)**	-262.145	(214.816)
$a_{18}$	Size <sub>t-1</sub>	0.009	(0.005)*	0.019	(0.007)***	0.016	(0.008)*
$a_{19}$	Growth <sub>t</sub>	0.299	(0.105)***	0.306	(0.091)***	0.519	(0.127)***
$a_{20}$	Education of local workforce	-0.597	(2.000)	-2.065	(2.541)	-0.346	(2.628)
$a_{21}$	IMR <sub>t</sub> (Inverse Mills ratio)	1.377	(2.072)	2.328	(2.253)	2.117	(2.546)
	$p$		1.875***		1.748***		1.700**
	Log-pseudolikelihood		-66.704		-51.496		-51.760
	Wald $\chi^2$ test		99.37 (19)***		105.50 (20)***		117.06 (20)***
	No. of observations		2,981		2,651		2,258
	No. of firms		496		437		373

Note: \*10% significance level; \*\* 5% significance level; \*\*\* 1% significance level. Robust standard errors and number of restrictions in parentheses. Significance of the parameter  $p$  refers to the test  $H_0: p = 1$ .

a similarly positive effect. Lastly, we did not generate clear predictions as to the coefficient of *NFounders* because opposing forces are likely to be at work. Accordingly, the coefficient of this variable is not significant.

Let us now consider firm-specific variables. VC investments accelerate the introduction of a middle-management level into a firm's organization (for a similar result, see Hellmann and Puri, 2002), but only when VC is obtained from an independent VC investor. *IVC* has a positive coefficient, significant at 5% in the full-information sample of Model (1). Conversely, the coefficient of *CVC*, denoting firms that obtained VC from a corporate VC investor, is not significant. The results for variables reflecting other "quality signals" that high-tech entrepreneurial ventures convey to uninformed third parties are somewhat mixed. The coefficient of the variable capturing participation in EU-funded research projects is always positive, and it is statistically significant at the 10% level in Models (1) and (3). Conversely, patent awards seem not to have any statistically

significant effect on the hazard rate.<sup>23</sup> Lastly, coherently with theoretical predictions of Table I, the variable *ERP* in Model (3) shows an insignificant coefficient being the result of opposite forces with none prevalent. In particular, the adoption of ERP systems seems to be only slightly more helpful in reducing the agency costs associated with the appointment of a middle manager than in addressing problems associated with information overload of owner-managers, but this predominance turns out to be statistically weak (for positive results related to intra-firm hardware communication technologies, see Delmastro, 2002. For evidence of the positive impact of adoption of ERP systems on the delegation of decisions, see Bloom et al., 2009).

We now turn our attention to industry-specific variables reflecting the characteristics of firms' business and technological environments. Our findings support the view that high-tech entrepreneurial ventures facing tougher competition are more inclined to appoint a middle manager, thus bringing support to the information processing view and confirming the positive relation between competition and the delegation of decision-making authority as highlighted by previous studies (Lin and Germain, 2003; Acemoglu et al., 2007; Meagher and Wait, 2008, Bloom et al., 2010). *Price competition* and *Market fragmentation*, respectively, have a positive and negative coefficient in all models. The coefficient of the latter variable is always significant at 5% or better; that of the former variable is significant (at 10%) only in Model (1).<sup>24</sup> Contrary to predictions inspired by the decentralization of incentives perspective, *Appropriability* capturing firms' ability to protect their novel technologies is negatively related to the likelihood of creating a middle-management level. Its coefficient is negative, and it is significant at 5% in both Models (1) and (2). Thus, there is no evidence at all that agency costs associated with appropriability hazards discourage the appointment of a middle manager. Finally, the hazard rate is found to increase with the uncertainty of the business environment in which firms operate and to decrease with the difficulty that investors experience in assessing firms' value as captured by *Business uncertainty* and *Uncertainty in firm quality*, respectively.

Finally, both (firm) *Size* and *Growth* exhibit positive coefficients that are significant at conventional levels. These results are in line with both theoretical predictions and the stylised fact, highlighted by the empirical literature on firms' organizational design (Delmastro, 2002; Wang, 2009; Guadalupe and Wulf, 2010. See also Colombo and Delmastro, 2008, chapter 3), that the size of operations is a key determinant of the depth of the corporate hierarchy. Moreover, younger entrepreneurial ventures are less likely to appoint a middle manager than their older counterparts. In fact, the hazard rate shows a

23. We also estimated the models substituting the variable  $Patent_{t-1}$  with the variable  $VPatent_{t-1}$  capturing the discounted patent stock of the firm at  $t-1$ . It is calculated as follows:  $VPatent_{t-1} = (1 - 0.15)VPatent_{t-2} + NPatent_{t-1}$ , where 0.15 is the Griliches constant depreciation rate of the patent stock and  $NPatent_{t-1}$  is the number of patents awarded to the firm at time  $t-1$ . Moreover, we replaced *EUproject* with the number of EU-funded R&D projects in which a firm was participating at time  $t-1$ . The results are almost unchanged with respect to those illustrated here.

24. Guadalupe and Wulf (2010) find that increasing competitive pressures generated by trade liberalization led to the flattening of the hierarchy of large US firms in the early 1990s, with the elimination of intermediate managerial layers between the CEO and division managers (i.e., a *reduction* of the depth of the hierarchy). This result is only apparently at odds with those presented here. Increased competition makes decisions more urgent, thereby leading to the decentralization of decision-making. In large US firms, as documented by Rajan and Wulf (2006), decision-making authority is increasingly delegated to division managers who directly report to the CEO. This move makes firm hierarchies flatter. Among the owner-managed entrepreneurial ventures considered in the present study, decision-making authority is generally concentrated at the top of a two-layer pyramid. The decentralization of decision-making typically implies the creation of a middle-management layer.

positive duration dependence, with the value of the  $p$  parameter significantly larger than unity (at 1%). Lastly entrepreneurial ventures' decisions to create a middle-management layer do not appear to be affected by the level of education of the local workforce.

#### 4.5 EVALUATING THE ECONOMIC MAGNITUDE OF THE EFFECTS OF THE EXPLANATORY VARIABLES

It is interesting to assess the economic magnitude of the explanatory variables of the model in addition to their statistical significance in order to gauge the explanatory power of competing theories and, more generally, to evaluate the relevance of the various theoretical backgrounds. For this purpose, we proceeded as follows. First, we defined a "benchmark" firm, setting continuous explanatory variables at their mean value and discrete explanatory variables at their median value. Based on the estimates of Model (1), we then calculated the probability of this firm's creating a middle-management level by 12 years after its inception. Quite unsurprisingly, this probability was fairly low (slightly less than 3%). This again confirms the serious obstacles that Italian high-tech entrepreneurial ventures encounter in this domain. Then, we grouped the explanatory variables according to their expected effects on the parameters of interest considered in our model:  $q_i$ ,  $\pi$ ,  $\rho$  and  $F$ . Note that some of these variables are assigned to multiple groups because they are expected to have multiple effects (e.g., *Business uncertainty*). Third, we set these variables at values corresponding to either their 90<sup>th</sup> or their 10<sup>th</sup> percentile depending on whether their predicted effect on the probability of creating a middle-management position was positive or negative. Fourth, we recalculated the probability of a middle-manager being appointed by year 12 after the firm was founded.

Before illustrating the results of this exercise in Table V, we considered the magnitude of the joint effect of *Size* and *Growth* using a similar procedure. These variables which are the most frequently considered by the empirical literature on the determinants of the depth of firms' corporate hierarchy, emerge as having limited economic influence, though that influence is statistically significant. With all other variables at their mean or median values, for a large and rapidly growing entrepreneurial venture, the likelihood of creating a middle-management layer is only 3.8%.

Turning to Table V, our findings highlight that variables that reflect the opportunity cost of owner-managers' time ( $q_i$ ) play a crucial role in driving the appointment of a middle manager. This consideration especially applies to industry-specific characteristics that make timely decisions fundamental. When *Price competition* and *Business uncertainty* are set at their 90<sup>th</sup> percentile and *Market fragmentation* is set at its 10<sup>th</sup> percentile, the probability of switching to a three-layer hierarchy by year 12 after inception increases to 13%. The hazard ratio is equal to 4.62, significant at 5%. In accordance with the "knowledge hierarchy" argument, the probability of creating a middle-management layer is also quite sensitive to the human capital characteristics of founders. When the human capital variables measuring (i) years of university-level education in economics and management and in technical and scientific fields and (ii) years of work experience are all set at their 90<sup>th</sup> percentile and the number of founders is low ( $N_{Founders}$  set at its 10<sup>th</sup> percentile), the probability increases to more than 15% with a hazard ratio of 5.54 (significant at 10%).

Third, our study suggests that the effect of the variables that reflect the information advantage eventually possessed by middle managers ( $\pi$ ) is negligible. When *Hetero-work* and *Business uncertainty* are set at their 10<sup>th</sup> and 90<sup>th</sup> percentiles, respectively, reflecting a situation in which the use of an agent's specific knowledge is very valuable for an

**TABLE V.**  
**ECONOMIC MAGNITUDE OF THE EFFECTS OF THE EXPLANATORY**  
**VARIABLES OF THE CREATION OF A MIDDLE-MANAGEMENT LEVEL**

Determinants	Hazard Ratio	Probability of Creation of a Middle-Management Level
Benchmark	1	2.97%
<b>Information-Processing</b>		
<i>Opportunity cost of owner-managers' time (<math>q_t</math>)</i>	25.60 (31.55)***	53.82%
Urgency of decisions ( <i>Price competition = 90<sup>th</sup>, Market fragmentation = 10<sup>th</sup> &amp; Business uncertainty = 90<sup>th</sup></i> )	4.62 (2.84)**	13.02%
Number and human capital of owner-managers ( <i>NFounders = 10<sup>th</sup>, Tech-education = 90<sup>th</sup>, Eco-education = 90<sup>th</sup> &amp; Workexp = 90<sup>th</sup></i> )	5.54 (5.80)*	15.40%
<b>Decentralisation of Incentives</b>		
<i>Information advantage of the middle manager (<math>\pi</math>)</i>	0.79 (0.16)	2.35%
Heterogeneity of owner-managers' competencies ( <i>Hetero-work = 10<sup>th</sup></i> )	0.70 (0.14)*	2.09%
Business uncertainty ( <i>Business uncertainty = 90<sup>th</sup></i> )	1.13 (0.07)*	3.35%
<i>Agency costs (<math>\rho</math>)</i>	0.19 (0.14)**	0.57%
Number of owner-managers & Owner-managers' management competencies ( <i>NFounders = 90<sup>th</sup> &amp; DManager = 1</i> )	0.50 (0.35)	1.49%
Business uncertainty ( <i>Business uncertainty = 10<sup>th</sup></i> )	0.88 (0.06)*	2.63%
Appropriability ( <i>Appropriability = 90<sup>th</sup></i> )	0.43 (0.14)**	1.30%
<b>Labour Market Factors</b>		
<i>Cost of hiring the middle manager (<math>F</math>)</i>	10.90 (15.92)*	28.03%
Firms' awards ( <i>Patent = 1 &amp; EUProject = 1</i> )	3.13 (2.48)	9.01%
Independent venture capital ( <i>IVC = 1</i> )	5.21 (3.86)**	14.54%
Corporate venture capital ( <i>CVC = 1</i> )	0.42 (0.40)	1.27%
Uncertainty in firm quality ( <i>Uncertainty in firm quality = 10<sup>th</sup></i> )	1.57 (0.71)	4.64%

*Note:* Comparisons are based on the estimates of Model 1 of Table IV. Probabilities are obtained as: [1-Survival function]. Weibull survival function is:  $\exp(-\lambda t^\beta)$  where  $\lambda = \exp(\beta'x)$ . Hazard ratio is the ratio between the hazard function computed at the benchmark case and the hazard function obtained modifying only the value of the covariates of interest (see infra). Weibull hazard function is:  $p\lambda t^{\beta-1}$ . The benchmark case corresponds to a 12 years old firm with all explanatory variables at their mean value. Remaining probabilities and hazard ratios are obtained from the benchmark case setting continuous (dummy) variables of interest at their 10<sup>th</sup> percentile (min = 0) if theory predicts a negative sign or 90<sup>th</sup> percentile (max = 1) if theory predicts a positive sign. Standard errors in parentheses estimated through the Delta method. \*10% significance level; \*\*5% significance level; \*\*\*1% significance level.

entrepreneurial venture, the probability is lower than the benchmark value (2.35%) and the hazard ratio equal to 0.79 is not significant.

Similarly, we do not find any evidence that agency costs ( $\rho$ ) deter the appointment of middle managers. When the variables reflecting the extent of these agency costs are set to the appropriate percentile so as to delineate a scenario characterized by low  $\rho$  (i.e., *NFounders*, *DManager*, and *Appropriability* at the 90<sup>th</sup> percentile, *Business uncertainty* at the 10<sup>th</sup> percentile), the estimated probability of the creation of a middle-management level declines to 0.57% (hazard ratio = 0.19, significant at 5%), contrary to theoretical predictions.

Lastly, labour market imperfections turn out to play a crucial role in deterring the creation of a middle-management position by a high-tech entrepreneurial venture. For firms that (i) incur low transaction costs in the search for suitable middle manager candidates due to the help of an independent VC investor, and (ii) encounter limited adverse selection problems because the firm is able to credibly signal its quality to

uninformed third parties through the receipt of a VC investment or a subsidy from the EU (patent awards do not seem to have a similar “certification effect” here) or because quality is easier to assess in its industry of operation (i.e., *Uncertainty in firm quality* is set to the 10<sup>th</sup> percentile), the likelihood of appointing a middle manager increases substantially (up to 28%). The importance of supply side factors associated with adverse selection problems is also attested by the positive duration dependence of the hazard rate, as illustrated in Figure 1. Finally, although the small numbers involved recommend caution (only 3% of our sample firms are VC-backed; see again Table III), being backed by an independent venture capitalist appears as the single most influential variable (hazard ratio = 5.21, significant at 5%). This result is not surprising, given the well-known role played by venture capitalists in the professionalization of investee companies (on this issue, see Hellmann and Puri, 2002; Bottazzi et al., 2008; Colombo and Grilli, 2010).

#### 4.6 ROBUSTNESS CHECKS

To examine whether the results presented in the previous section are robust, we ran several additional estimates. First, we performed a Monte Carlo simulation exercise, running all models including in the sample the 22 sample firms that introduced a middle-management level but did not indicate precisely when. The sample size on which iterations are based increased to 518 firms for Model (1), 459 for Model (2) and 395 for Model (3). More specifically, to solve this left censoring problem, we randomly assigned to these 22 firms the year of creation of their first middle-management position and estimated the Weibull duration models for the augmented samples. The exercise was repeated 1,500 times for each regression. Table A3 (see the on-line appendix) reports the average coefficient estimates and standard errors. The results for all three models are in line with those previously presented.

Second, we ran all models while including in the sample only those sample firms that did not experience any change in their team of owner-managers and excluding all others. We also excluded VC-backed firms. The sample size shrinks considerably but less than one may expect. As a matter of fact, 58.1% of the sample firms did not experience any change in their team of owner-managers, still allowing us to run meaningful regressions. Although the statistical significance of the estimates is obviously weakened by the smaller sample size, the results shown in Table VI do not highlight any dramatic change in comparison with those presented in the previous section, pointing to the robustness of the imprinting assumption and more generally of the empirical analysis previously performed. The only major discrepancies are the loss of significance of the coefficients of the *Market fragmentation* and *Business uncertainty* variables and the impact of *NFounders*, which now turns out to be positive and statistically significant in Model 1 (albeit only at 10%). This latter result suggests that for firms with a stable core of founders, the agency costs allegedly engendered by the appointment of a middle manager and the delegation of decision authority to her decrease more rapidly with an increase in the size of the founding team than do information overload problems.

Third, we checked whether the decision to introduce a middle-management layer is influenced by firms’ financial conditions. For this purpose, we re-ran Model (1) from Table IV including two additional covariates: *Cash flow/sales* and *Current debt/current assets*, both delayed at time  $t-1$ . Data for these variables were available for a subsample of 334 firms. As was expected, the coefficients of these two variables turned out to be positive and negative, respectively, but neither was significant. More importantly, the results of the estimates for the variables of interest were again unchanged.

**TABLE VI.**  
**THE DETERMINANTS OF THE CREATION OF A MIDDLE-MANAGEMENT LEVEL: ROBUSTNESS CHECKS ON FIRMS WITH NO CHANGES OVER TIME IN THE COMPOSITION OF THE OWNER-MANAGER TEAM**

	Model 1		Model 2		Model 3	
$a_0$ Constant	62.568	(37.960)*	71.137	(35.820)**	36.177	(57.382)
$a_1$ Eco-education	1.245	(0.613)**	1.242	(0.562)**	1.054	(0.565)*
$a_2$ Tech-education	0.022	(0.207)	0.076	(0.234)	0.031	(0.245)
$a_3$ Workexp	0.074	(0.098)	0.041	(0.138)	0.100	(0.085)
$a_4$ Hetero-work	0.588	(1.525)	0.821	(1.436)	0.763	(1.873)
$a_5$ DManager	0.731	(0.924)	0.574	(0.923)	0.790	(0.945)
$a_6$ DEntrepreneur	–	–	– 0.318	(0.595)	–	–
$a_7$ NFounders	0.442	(0.235)*	0.394	(0.254)	0.375	(0.256)
$a_8$ ERP <sub><i>t</i>-1</sub>	–	–	–	–	0.657	(0.658)
$a_9$ Patent <sub><i>t</i>-1</sub>	– 0.471	(0.720)	– 2.130	(1.052)**	– 0.755	(0.814)
$a_{10}$ EUproject <sub><i>t</i>-1</sub>	1.522	(0.957)	2.401	(1.097)**	1.700	(0.966)*
$a_{11}$ Appropriability	– 15.356	(6.611)**	– 17.016	(5.656)**	– 12.359	(7.819)
$a_{12}$ Price competition	10.158	(3.936)**	8.637	(3.358)**	8.391	(3.288)**
$a_{13}$ Market fragmentation	1.674	(11.319)	4.865	(8.463)	1.464	(9.417)
$a_{14}$ Business uncertainty <sub><i>t</i>-1</sub>	– 1.254	(1.567)	– 0.676	(1.583)	– 1.113	(1.616)
$a_{15}$ Uncertainty in firm quality	– 742.743	(400.027)*	– 814.000	(439.234)*	– 566.779	(474.173)
$a_{16}$ Size <sub><i>t</i>-1</sub>	0.064	(0.015)**	0.061	(0.014)**	0.061	(0.014)**
$a_{17}$ Growth <sub><i>t</i></sub>	0.292	(0.132)**	0.210	(0.104)**	0.487	(0.226)**
$a_{18}$ Education of local workforce	3.282	(4.079)	2.982	(3.616)	5.049	(6.015)
$a_{19}$ IMR <sub><i>t</i></sub> (Inverse Mills ratio)	2.038	(2.890)	2.271	(3.313)	0.395	(4.116)
$p$		1.734***		1.911***		1.669***
Log-pseudolikelihood	– 14.186		– 14.279		– 13.018	
Wald $\chi^2$ test		41.53 (17)**		57.02 (18)**		69.86 (19)**
No. of observations		1,639		1,486		1,323
No. of firms		288		260		230

Note: \*10% significance level; \*\* 5% significance level; \*\*\* 1% significance level. Robust standard errors and number of restrictions in parentheses. Significance of the parameter  $p$  refers to the test  $H_0: p = 1$ .

Another important robustness check aimed at verifying to what extent our findings might have been driven by endogeneity concerns. Recognizing that in this case it is arduous to find suitable truly exogenous instruments for those variables most suspected to give rise to this type of problems (e.g., variables capturing size and growth, VC investments and innovation achievements), we tackled the issue of endogeneity by investigating whether results could be distorted by the possible presence of (a) unobserved heterogeneity and (b) reverse causality through methods that do not contemplate the use of any specific instrument. First, as it is typically done in survival studies (e.g., Cameron and Trivedi, 2005, p. 612), to check for the presence of unobserved heterogeneity, we estimated the models illustrated in Table IV adopting a (shared) frailty specification (Hougaard, 1995; Gutierrez, 2002). A frailty model accounts for the presence of a multiplicative effect on the individual hazard function, allowing a test of the presence of unobserved heterogeneity driven by an additional parameter  $\theta$  that measures the degree of dispersion of individual hazard rates with respect to the sample average. Accordingly, the statistical insignificance of the frailty variance component indicates negligible (unobserved) heterogeneity. Assuming an inverse Gaussian distribution for frailty, the results of the estimates are very similar to those exposed in Table IV, and a series of likelihood ratio tests does not reject the null hypothesis of the parameter  $\theta$  being equal to zero

( $\chi^2(1) = 0.01$  in Model 1;  $\chi^2(1) = 0.01$  in Model 2; and  $\chi^2(1) = 0.70$  in Model 3). Second, risk of reverse causality relationships was tested for those variables that being more persistent over time, namely *Size* and *Growth*, were most suspected to be in a reversed relationship with our dependent variable. To this purpose, we conducted a “placebo leads” test (e.g., Bartel and Harrison, 2005; Samila and Sorenson, 2010). Considering Model 1 that uses full information available on the series, the introduction of leads of these covariates in the specification reveals that none of these leads are either individually or jointly significant (the null hypothesis of an insignificant impact is always accepted at usual confidence levels,  $\chi^2(2) = 1.80$  for *Size* at time  $t$  and *Growth* at time  $t+1$  and  $\chi^2(2) = 0.80$  for *Size* at time  $t+1$  and *Growth* at time  $t+2$ ). In addition, our original findings regarding the impact of *Size* and *Growth* (measured at  $t-1$  and  $t$ , respectively) and that of all the other variables of interest remain similar.

Lastly, as a final check, for those continuous variables for which we had mixed theoretical predictions, that is, *NFounders* and *Business uncertainty*, we also inserted a squared term in the specification of Model (1) so as to check for the existence of nonlinear effects (i.e., a U- or inverted U-shaped relation between these variables and the hazard rate). The coefficients of the squared terms were not significant. For the sake of synthesis, the results of all these additional estimates are not reported in the text (they are available from the authors upon request).

## 5. DISCUSSION AND CONCLUSIONS

The aim of this paper was to examine the determinants of the depth of the corporate hierarchy of entrepreneurial ventures, a key aspect of their organization, and to test the predictions advanced by different streams of the theoretical economic literature. More precisely, we have analysed the transition from a two-layered organization composed only of owner-managers and line workers to a three-layered one including a middle-management level. This transition involves partial delegation of decision-making authority to a newly appointed middle manager and is a critical though underresearched juncture in the process of “managerial professionalisation” of owner-managed entrepreneurial ventures. In the empirical part of the paper, we have considered a sample of 524 Italian owner-managed high-tech entrepreneurial ventures. Our econometric results provide interesting new insights highlighting the relative explanatory power of different streams of theoretical literature.

First of all, in accordance with the information processing stream, our findings suggest that the opportunity cost of owner-managers’ time has a positive crucial effect on the creation of a middle-management level in entrepreneurial ventures. Notably, this move is more likely when timely decisions are fundamental because of strong competitive pressures and the unpredictability of the business environment. Our findings are also consistent with the concept of an entrepreneurial venture as a “knowledge hierarchy” (Garicano, 2000; Garicano and Rossi-Harsberg, 2006). The greater the human capital of owner-managers as reflected in their university-level education in economics and management and to a lesser extent their work experience prior to firm’s founding, the greater the hazard rate of appointing a middle manager.

Second, our results do not lend support to arguments inspired by the decentralisation of incentives literature. We failed to detect any compelling evidence that the creation of a middle-management layer is driven by the desire of firms’ owner-managers to take advantage of the specific knowledge possessed by individuals who are not part of the

top management team. In particular, contrary again to expectations, firms with owner-manager teams composed of individuals with similar work experience are less likely to appoint a middle manager than are those with more heterogeneous teams. A possible explanation lies in the greater transaction costs that homogeneous founding teams encounter in searching for suitable middle manager candidates who have different experience from their own one, thereby generating path-dependency in firm's evolution. In a similar vein, Beckman and Burton (2008) while studying the evolution of top management teams, find that narrowly experienced founding teams have trouble adding functional expertise not already embodied in the team. Another reason may be that for the type of firms we analysed, high-tech entrepreneurial ventures, a middle manager job is less than ideally attractive for individuals with valuable specific knowledge. Our data show that high-powered incentive-based compensation schemes are not widely diffused among Italian high-tech entrepreneurial ventures, possibly as a result of the difficulty of going through an IPO and the associated limited appeal of stock options and other stock-based incentives. It may then be the case that when an individual possesses valuable specific knowledge, the best way for a high-tech entrepreneurial venture to use that knowledge in decision-making is to offer her an owner-manager role. We leave a test of this proposition to future work.

Moreover, we did not find any systematic evidence that the agency costs generated by the creation of a middle-management level discourage this move. In particular, contrary to our predictions, the tightness of the appropriability regime in the industry in which firms operate was found to have a negative effect on the hazard rate. This may indicate that when the appropriability regime is tight, firms are protected from innovation-related competitive pressures. In turn, while making decisions less urgent, this reduces the opportunity cost of owner-managers' time.

Third, previous studies on the depth of the corporate hierarchy did not consider imperfections in the managerial labour market. We expected these imperfections to hinder the switch of entrepreneurial ventures to a three-layer corporate hierarchy. Our findings support this view. They clearly show that the transaction costs that entrepreneurial ventures incur in the search for suitable candidate middle managers and the adverse selection problems that make their employment offers unappealing have negative effects that are both statistically and economically significant on the creation of a middle-management position. We consider this as an important, original addition of this study to the extant organizational design literature.

According to our estimates, being backed by an independent VC investor is a significant driver of the creation of a middle-management position by high-tech entrepreneurial ventures; while, quite interestingly, no such effect shows up for CVC-backed firms. This result conforms to the view, quite popular in the VC literature, that the identity of the investor matters (see among others Gompers and Lerner, 2000; Bottazzi et al., 2008; Bertoni et al., 2010, 2013). The reason may be that in a CVC-backed venture, tasks that would normally be assigned to middle managers are performed on a part-time basis by personnel of the corporate investor. Alternatively, because CVC investments are generally used by large incumbent firms for technology window purposes (e.g., Siegel et al., 1988), CVC-backed firms may be induced to specialise in the development of new technologies. The associated reduction of the complexity of their value chain, while lowering the opportunity cost of the time of owner-managers, reduces the need for a deeper corporate hierarchy. Admittedly, these arguments are speculative. The differences in the rates of managerial professionalization of entrepreneurial ventures engendered by different types of VC investors is a promising topic for future research.

Our study has some limitations that provide further interesting avenues for future research. The most critical limitation is a lack of information on changes over time in the team of firms' owner-managers. Accordingly, we were forced to proxy the characteristics of owner-managers using those of founders. Should time-varying information on the composition of teams of owner-managers be available, one could get further insights into the mutual relations between changes in the team of owner-managers and the appointment of a middle manager. Our findings indicate that the desire of firms to extend the information set used in decision-making does not lead to the creation of a middle-management layer. However, it may lead to the enlargement of the owner-managers' team. In turn, the appointment of a middle manager while reducing information overload, may make the enlargement of the owner-management team less necessary. Moreover, it would be interesting to collect more comprehensive data on the type of tasks assigned to middle managers, the specific competencies they possess, the nature of their compensation schemes, and whether they are recruited in the labour market or are promoted from the line workers' ranks. Unfortunately, we were able to collect this information for only slightly more than half of the sample firms that had created a middle manager position. If this information were available for a larger number of firms, we could study whether the determinants of the appointment of a middle manager vary according to (i) the function of the new manager (e.g., chief operating officer as opposed to sales manager), (ii) the type of compensation scheme (incentive-based or fixed salary), (iii) whether the appointed manager comes from inside or outside the firm, and (iv) her previous work experience. This would also enrich our understanding of the role of transaction costs and adverse selection problems in the managerial labour market in hindering the managerial professionalization of entrepreneurial ventures.

In spite of these limitations, our study offers an interesting contribution to both the economics of organizational design and the entrepreneurship literature. It also has important implications for policy-makers. Traditionally, policy measures in support of start-ups have been advocated on the basis of imperfections in capital markets and the public good nature of R&D expenses (e.g., Holtz-Eakin, 2000). Here, we have documented that entrepreneurial ventures also suffer from severe imperfections in the managerial labor market that hinder their managerial professionalization and thus may negatively affect their performance and in turn have negative macro-economic consequences (Hsieh and Klenow, 2009). Removing these imperfections and thus alleviating the misallocation of managerial resources is an additional important objective for policy makers, and our study gives them some suggestions regarding how to proceed in this domain. First, selective policy schemes that target young entrepreneurial ventures, if they are administered by reputable governmental institutions, can be very helpful in signalling the quality of these firms to uninformed third parties, including would-be middle managers (Lerner, 1999). Second, we have shown that VC financing obtained from independent VC investors has a sizable positive effect on the ability of firms to appoint middle managers. Accordingly, this is an additional reason to place the promotion of the VC sector quite high on the policy agenda, at least in countries like most of those in Continental Europe, where the VC sector both was relatively underdeveloped and has been badly affected by the financial crisis.

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