NETWORK POSITION AND THE PROBABILITY OF BEING ACQUIRED: AN EMPIRICAL ANALYSIS IN THE BIOPHARMACEUTICAL INDUSTRY

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ABSTRACT

This article examines the relationship between the firm's direct ties, its inter-firm network prominence and its likelihood of being acquired. We argue that a firm’s direct ties and prominence enhance the firm’s visibility and signal its quality – and thus foster the firms' likelihood of being acquired. However, high levels of direct ties also provide access to strategic resources and simultaneously signal the firms’ status and increase the firm’s ability to remain independent and thus reduce its likelihood to be acquired. Thus, we posit the overall relation as an inverted U-shape. Furthermore, we show that for firms that undergo an initial public offering (IPO), the aforementioned relation becomes much weaker. We empirically test our hypotheses in the biopharmaceutical industry and discuss important theoretical and managerial implications.

Keywords: signaling theory, network theory, social capital, acquisition, biopharmaceutical.

INTRODUCTION

"*In addition to Amylin, BioSeek has had collaborations with numerous pharmaceutical and biotechnology companies including Merck-Serono, UCB, and Dainippon Sumitomo*" (BusinessWire, 2009).

The quote, from Asterand Bioscience's announcement of its acquisition of BioSeek Inc. in 2009 is an example of the importance of a target's inter-firm agreements to prospective acquirers. Surprisingly, social capital (SC) literature has still not examined how a firm's network position influences its likelihood to be acquired. Past work on the impact of network positions has focused on related topics such as the firm's survival (Uzzi, 1996; Brüderl and Preisendörfer, 1996; Mitchell and Singh, 1996; Watson, 2007), the firm's dissolution (Pennings et al., 1998) and the firm's propensity to make acquisitions or mergers (Haunschild, 1993; Hoang, 1997; Lin et al., 2009; Yang et al., 2011). Further, research on mergers and acquisitions (M&A) has not used a network perspective but rather focused on dyadic relations between the target and acquirer, (i.e. be they customers, suppliers, or competitors). This gap is also relevant from a managerial point of view. Most firms looking for a possible buyer highlight their inter-firm relations among the "reasons to be bought". Furthermore, market business intelligence websites routinely provide information on the firms' inter-organizational deal activity[1].

In this research, we aim to fill this gap by providing possible explanations on how and why a firm's network position influences its likelihood to be acquired. We build on signaling and network theories to explain how and why a firm's direct ties and prominence in its ego-network influence its likelihood to be acquired. In this paper, the focus is on inter-firm networks based on company-to-company relationships (Grandori and Soda, 1995).

We argue that the firm's direct ties and prominence are *visibility-enhancing signals* (Pollock and Gulati, 2007) that allow the firm to "stand-out from the crowd" and get noticed by potential

[1](See for instance https://www.pharmamedtechbi.com).

acquisition suitors. Moreover, the firm's direct ties and network prominence *signal* the firm's *quality* that helps reduce the information asymmetry between the firm and the market (Stuart, 2000; Ozmel et al., 2013), and thus increasing, in this way, its likelihood to be acquired.

However, firms with high levels of direct ties have *access* to valuable resources that improve firm performance, boosting the firm's organic growth and, therefore, reducing the likelihood of its acquisition (Ahuja, 2000; Koka and Prescott, 2002; Soh, 2003; Salman and Saives, 2005; Zaheer and Bell, 2005; Schilling and Phelp, 2007; Gilsing et al., 2008; Wu, 2008; Vanhaverbeke et al., 2009; Zaheer et al, 2010; Vanhaverbeke et al., 2012; Wincent et al., 2013). Furthermore, a highly prominent firm signals its *status*, which enhances its organizational performance and thus contributes to the firm's development and independence (Podolny, 1993; Podolny, 2001; Shipilov and Li, 2008; Ozmel et al., 2013).

We build on these findings from SC research to construct a theoretical framework that explains why an ego firm's direct ties and network prominence have an inverted U-shaped relation to its likelihood to be acquired by a predator.

Further, we build on multiple signaling literature (Pollock and Gulati, 2007) to explain how initial public offerings (IPOs) interact with the aforementioned inverted U-shaped relations. IPOs significantly influence a firm' likelihood to be acquired (Jain and Kini, 1999; Field and Karpoff, 2002; Ragozzino and Reuer, 2007; Hovakimian and Hutton, 2010).

We test our theoretical framework on a network of inter-firm relationships of 2083 biopharmaceutical companies over the period 2001-2010. We found significant support for an inverted U-shaped relation between a firm's direct ties, network prominence and its likelihood to be acquired. For firms that have an IPO, the relation between network positions and their likelihood to be acquired is significantly weakened.

Our study contributes to the social capital literature by showing mechanisms through which a firm's network position influences its likelihood to be acquired. In particular, our study highlights the connection between differences in network embeddedness and the signalling effect of visibility and quality on one hand and the effect of status and resource access on the other hand, to produce an inverted U-shaped relation between a firm's network positions and its likelihood to be acquired. Finally, we contribute to multiple signalling literature by showing the interaction between two different signals a firm can launch: signals emanating from its network position and from an IPO event.

In the next section, we present the theoretical framework. We then explain our methods. Finally, we discuss the results and their theoretical and managerial implications.

THEORY AND HYPOTHESES

The role of direct ties

Direct ties are one of the most considered network embeddedness features in social capital (SC) literature (Ahuja, 2000; Koka and Prescott, 2002; Salman and Saives, 2005; Wu, 2008; Vanhaverbeke et al., 2012). We argue that a firm's direct ties have a *signaling* and a *resource* access effect. As a firm's direct ties increase, the firm stands out from the crowd (e.g. Gulati and Higgins, 2003), thus increasing its likelihood to be acquired. At the same time, the firm also gains access to valuable resources through its direct ties that allow the firm to grow (e.g. Ahuja, 2000) to a point where its strength reduces its likelihood to be acquired. Consequently, the overall impact of a firm's direct ties on its likelihood to be acquired is an inverted U-shaped relation.

Building on *signaling theory*, an acquisition decision can be regarded as an information asymmetry problem (Spence, 1973; Spence, 2002; Connelly et al., 2011; Bergh et al., 2014). The *predator* - the acquiring firm - faces difficulty in assessing whether a possible *prey* has the quality it claims to possess. According to signaling theory, an effective signal creates a separate equilibrium between a prey that has high quality resources versus one that doesn't, thus reducing or even nullifying the adverse selection problem. Connelly et al, (2011) highlight studies where signaling theory has been applied extensively to explain how young firms signal their quality to potential IPO investors through different signals such as board characteristics (Certo et al., 2001; Filatotchev and

Bishop, 2002; Certo, 2003), former investments (Elitzur and Gavious, 2003; Janney and Folta, 2003; Janney and Folta, 2006), ownership (Filatotchev and Bishop, 2002; Busenitz et al., 2005; Jain et al., 2008; Bruton et al., 2009), and top management quality and reputation (Coff, 2002; Cohen and Dean, 2005; Higgins and Gulati, 2006; Jain et al., 2008; Zimmerman, 2008).

Scholars have also recognized network positions as signals (Stuart et al., 1999; Stuart, 2000; Gulati and Higgins, 2003; Nicholson et al., 2003; Ozmel et al., 2013). Stuart et al., (1999) and Stuart (2000) suggest that inter-firm relationships are signals that convey social status and recognition to existing and potential customers. According to Gulati and Higgins (2003), ties to prominent actors, reflect a young firm's value and mitigate the different types of uncertainty a firm faces. Nicholson et al., (2003) find that biotech companies that sign inter-organizational deals with pharmaceutical companies send a positive signal to prospective investors and receive substantially higher valuations. Finally, Ozmel et al. (2013) show how a new venture's prominent position in networks of company-to-company relationships can signal its quality and future prospects when it is costly to form and maintain such relationships. However, in order to reduce uncertainty, signals must first attract the attention of those who use them (Pollock and Gulati, 2007). In particular, we need to focus on how a signal increases a firm's likelihood of inclusion in the 'consideration sets' (Pollock and Gulati, 2007), i.e. in the possible list of prey. As a firm's direct ties increase, it launches a *visibility-enhancing signal* and the firm 'stands out from the crowd' (Pollock and Gulati, 2007). Moreover, a firm's direct ties may be with potential buyers. Previous relations are a highly significant driver of acquisitions (Balakrishnan and Koza, 1993; Gulati, 1995 and 1998). Previous relations make it possible for a firm to gather valuable information about its partner's resources, capability and reliability – thus making the information asymmetry problem less serious and, consequently, increasing the partner's likelihood of being acquired (Vanhaverbeke et al., 2002).

At the same time, a firm's direct ties signal its resources quality, higher reputation and trustworthiness. A firm with more direct ties is, indeed, probably sought after by other firms because of its valuable resources such as knowledge, technology, patents and products that it can share with its partners (Mowery et al., 1996; Inkpen, 1998; Holcomb and Hitt, 2007; Zhang et al., 2007). Furthermore, a firm's level of direct ties also reflects its capability to deal with inter-firm relationships (Barkema and Vermeulen, 1998; Anand and Khanna, 2000; Hagedoorn and Duysters, 2002; Villalonga and McGahan, 2005; Kale and Singh, 2007; Wang and Zajac, 2007) signaling in this way its reputation and trustworthiness (Ring and Van de Ven, 1992; Parkhe, 1993; Gulati, 1995; Dyer and Singh, 1998; Gulati et al., 2000; Hagedoorn et al., 2006). Thus, direct ties act as a "prism" that reflects information cues about the quality of the firm (Podolny, 2001; Soh et al., 2004) reducing the information asymmetry between itself and the market – and thus increasing its likelihood of being acquired.

Summarizing, the *signaling effect* of direct ties increases the visibility of the firm. The firm's visibility also becomes a signal of its quality and the probability of its acquisition further increases.

Nevertheless, at high levels of direct ties, the *resource effect* becomes relatively more significant than the signaling effect. Firms with relatively higher direct ties have greater direct access to valuable resources such as information (Gulati, 1999; Ahuja, 2000), capabilities and learning (Powell et al., 1996) and assets such as knowledge, technology, patents, services (Mowery et al., 1996; Inkpen, 1998; Holcomb and Hitt, 2007; Zhang et al., 2007). For instance, Gulati (1999) highlights the concept of network resources - i.e. firms derive resource benefits from their network positions.

A firm with many direct ties is likely to develop the necessary internal capabilities to absorb, internalize or exploit external resources (Barkema and Vermeulen, 1998; Anand and Khanna, 2000; Hagedoorn and Duysters, 2002; Villalonga and McGahan, 2005; Kale and Singh, 2007; Wang and Zajac, 2007). From the seminal work of Uzzi (1996), subsequent network based scholarship has focused on evaluating the impact of direct ties on the firm's economic-financial performance (Baum et al., 2000; Koka and Prescott, 2002; Wu, 2008) and innovation performance (Ahuja, 2000; Salman and Saives, 2005; Vanhaverbeke et al., 2012; Mazzola et al., 2014). For example, Salman and Saives (2005) found that by occupying a direct central network position, a firm is more likely to access useful knowledge from its direct partners and increase its innovation performance. Further, the rate of performance improvement enjoyed by the firm is higher when the firm accesses greater amounts of external resources through is direct ties. We argue that such performance improvement allows the firm to keep its independence by either resisting acquisition or by simply not becoming a soft takeover target.

Moreover, the signaling effect of direct ties is subject to diminishing returns (Cohen and Dean, 2005). In other words, at higher levels of direct ties, additional direct ties would have less signaling impact. At higher levels of direct ties, the signaling effect is marginally less important while the resource effect is relatively stronger because of the number of direct ties the firm can count on. Thus, for higher levels of direct ties in its ego network, the likelihood that the firm will be acquired is significantly lower.

Summarizing we formulate the following hypothesis:

Hypothesis 1: *A firm’s direct ties in its inter-firm network have an inverted U-shape relationship to the likelihood of being acquired.*

The role of network prominence

A firm has a prominent position in its ego network when it is either directly tied to many other firms or, connected to firms who are themselves linked to many actors (Koka and Prescott, 2008). Similar to our argument above, moderate levels of prominence (i.e. direct and indirect ties) increase the firm’s *visibility* and *quality* signals, thereby increasing the likelihood that the firm will be acquired. However, stronger levels of prominence denote the firm's *status*, a condition that has been associated with superior performance (Jensen, 2003; Shipilov and Li, 2008; Ozmel et al., 2013) and would consequently lower the firm’s likelihood to be acquired. Hence, the overall impact of a firm’s network prominence on the probability that it would be acquired is an inverted U-shape relation.

A firm’s prominence is a *visibility-enhancing* signal gained through either the ego's direct links or through the connections of highly prominent firms with whom the ego is connected. The firm’s signaling also works indirectly through firms connected with the ego, that are themselves highly connected, and are considered reliable and trustworthy sources of information. Prominence is a signal of unobservable quality (Jensen, 2003) especially for firms that are indirectly tied to the focal firm and cannot directly observe the quality of the target firm. Information asymmetry between a potential acquirer and a prominent target firm is reduced, thus increasing the target’s firm’s likelihood of being acquired. Visibility and quality signals derived from a target firm’s prominence are not restricted to direct ties. Thanks to indirect ties, the signaling effects derive from the furthest tentacles of the firm’s ego network (Stuart et al., 1999; Jensen, 2003; Ozmel et al., 2013) something which past M&A studies, based on dyadic relations, have not been able to assess.

Stronger levels of prominence have been associated with *status* (Benjamin and Podolny, 1999; Podolny, 2001) a network position in which the firm expresses its power (Bonachic, 1987), influence and legitimacy (Koka and Prescott, 2008), and prestige (Shipilov and Li, 2008; Ozmel et al., 2013).

A high-status firm can improve its performance through at least three mechanisms. First, the firm is in a better position to attract financial resources, from investors and banks, to finance its developing programs (Rao et al., 2000). Second, having a superior standing in the industry, the firm commands premium prices as it leverages its reputation to consumers and other actors for commensurate returns (Podolny, 1993; Shipilov and Li, 2008). Finally, when a high status firm ties up with a low-status one, it can ask for compensation as a price for its cooperation, acquiring in this way valuable resources at a reduced price.

Furthermore, thanks to the "*homophily*" mechanism (McPherson et al., 2001) a superior status allows the firm to obtain advantageous positions in resource exchanges with other firms that reduce its acquisition probabilities. Indeed, especially when transaction uncertainty is relevant, firms tend to collaborate with firms having similar status. This behavior reduces the risk of opportunism because fairness and commitment are more likely to happen among partners with similar status (Chung et al., 2000). However, by tying with a lower status partner, a high-status firm risks adversely affecting its own status in the considerations of similar status partners. Thus, a high-status firm is likely to have inter-organizational relations with other high-status firms that are more likely have valuable resources to exchange. Finally, firms may use their high status to lock-in customers to their products, reducing competitive pressure and increasing in this way their revenues (Shipilov and Li, 2008).

Summarizing, rising levels of network prominence allow the firm to enhance its visibility and quality signals, thus increasing the likelihood of its acquisition. However, as the firm becomes highly prominent, its signaling effect is less relevant due to the diminishing returns effect; thus, the status effect dominates and increases the firm's independence and thus reduces the likelihood of its own acquisition. Hence, we formulate the following hypothesis:

Hypothesis 2: *The firm's prominence in its inter-firm network has an inverted U-shape relation to the likelihood of being acquired.*

The role of an IPO event

An Initial Public Offering (IPO) is a significant signaling and resource mobilization method that has been highlighted in the management and entrepreneurship literature and thus may influence a firm's likelihood to be subsequently acquired. Thus, we explore how IPOs may interact with a firm's network positioning in determining its likelihood of being acquired.

A wide stream of literature considers IPOs and takeovers as strictly related to each other. An IPO has been considered as a signal a firm launches as the first stage of an acquisition process (e.g. Field, 1999; Jain and Kini, 1999). According to this argument, firms issue IPOs to obtain a market value of their assets, which facilitates the sale of the firm either gradually through a reduction in ownership or immediately through a subsequent acquisition. Thus, an IPO works as a signal to prove the firm's value and the quality of the firm's resources through a market evaluation, therefore increasing the firm's likelihood of being acquired (Brennan and Franks, 1997).

However, through an IPO, a firm acquires the necessary resources to develop its growth strategies and thus increases the firm's capacity to resist any future attempts at being taken over through acquisitions. Moreover, IPO firms can take advantage of the cash raised in the IPO, subsequent access to public financing and the ability to fund any future acquisitions with publicly traded stock to strengthen its position and hence reduce any likelihood of being acquired (Field 1998; Hovakimian and Hutton, 2010).

We argue that, relative to the firm's network positions such as direct ties and prominence, an IPO is a stronger visibility-enhancing signal for the firm (Pollock and Gulati, 2007). Indeed, firms that undergo an IPO become well known to the financial, economic and institutional operators. Also within the industry, IPO firms are highly visible. An IPO is also a signal of the quality of the firm's products (Stoughton et al., 2001) and its potential sales and earnings before interest, taxes, depreciation and amortization (Zheng et al., 2007). Thus, e can argue that going through an IPO is such a strong visibility and quality signal for the firm that it completely subsumes the visibility and quality-signaling role of network positioning. Therefore, the signaling impact of direct ties and prominence for IPO firms is less relevant, or even irrelevant, than for non IPO-firms. Furthermore, because an IPO indubitably provides the firm with resources and status, the likelihood of its acquisition reduces. Indeed, through an IPO the firm obtains the necessary amount of cash to develop its growth programs. Such resources are even more significant considering that the firm can use its financial strength to access further financial resources or to use publicly traded stock to acquire some other external assets. Thus, the amount of resources obtained through an IPO makes the firm stronger and therefore less vulnerable to acquisition predators.

Finally, much of the IPO research includes a discussion on the role of the IPO and the firm's status for several reasons (Field, 1999; Field and Karpoff, 2002; Pollock and Gulati, 2007; Hovakimian and Hutton, 2010). First, an IPO firm is included in public lists of funded companies; this allows the IPO firm to be differentiated from other companies and to access, via a "*homophily*" mechanism, value from associating with firms having the same status. Second, the firm gets access to financial and institutional partners who may help the firm to reinforce its reputation. Third, by going public, the firm can attract to its board, prestigious directors that might significantly contribute to the prestige and reputation of the firm. Finally, public firms are usually subject to relatively more stringent monitoring and control by authorities and this reinforces the reliability and trustworthiness of the firm itself. The status obtained through an IPO allows the firm to develop takeover defense strategies (Field and Karpoff, 2002). Concluding, by overshadowing the signaling effect of direct ties and prominence whilst additionally providing resources and status that allow the firm to defend itself from takeovers, an IPO may reduce or, even, nullify the effect of direct ties and network prominence on the likelihood to be acquired.

However, this negative moderating effect is not symmetric. Indeed, once a firm has an IPO, how is it differentiated from other IPO-firms? Network features can help in this case by providing a complementary signal (Gulati and Higgins, 2003). In the case of IPO firms, since they are already visible, further differentiation among IPO firms would involve stronger signals from the network, i.e. a high level of direct ties and network prominence. A high level of direct ties may place IPO firm in connections with possible acquirers, increasing the probability to be included in a list of companies to buy. Hence, a highly prominent IPO firm is differentiated from the others, providing a "network status" alongside the "IPO status". Thus, strong values of direct ties and prominence, by providing complementary signals to an IPO firm, allow it to differentiate from the other IPO-firms and attenuate the negative effect of the network features on the likelihood to be acquired. Summarizing the above reasoning we hypothesize:

Hypothesis 3: *The curvilinear (inverted U-shaped) relationship between the firm's direct ties and prominence and the likelihood of the firm being acquired will become weaker if the firm undergoes an IPO. However, for high values of direct ties/prominence, the negative moderation effect of the IPO is attenuated.*

Figure 1 is

a graphical representation of the moderator's effect of IPO on the relation between the firm's direct ties/prominence and the probability to be acquired. Thus, following the considerations stated in H3, an IPO produces a U-shaped relationship nested within (i.e. vertically under) the relationship (the dotted line in figure 1) for the non-IPO case (the continuous line of figure 1). However, as depicted in Figure 1, for strong values of direct ties/prominence this negative moderator effect is attenuated as strong direct ties and prominent positions allow differentiating among IPO firms contributing to signaling them for possible acquisitions.

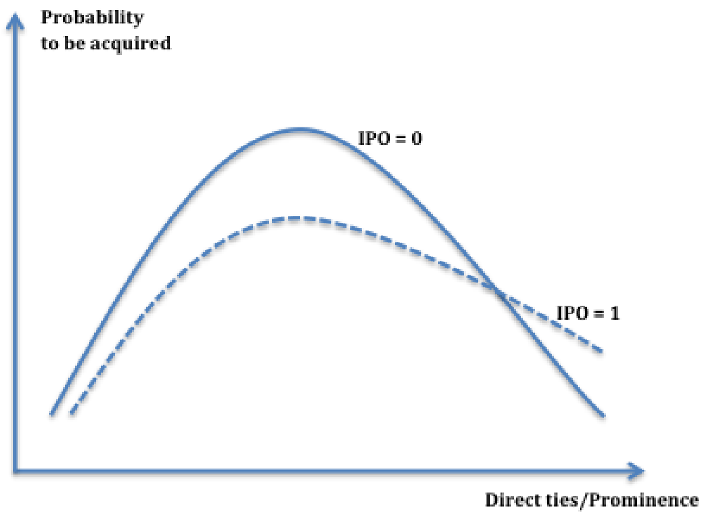

Figure 1. Effect of IPO on the relationship between direct ties/prominence and firm's acquisition

RESEARCH METHOD

Sample and Data

We empirically test the hypotheses in the biopharmaceutical industry. Indeed, with the advent of biotechnologies, pharmaceutical companies have lagged on research productivity (DiMasi et al., 2003; Goozner, 2004; Bradfield and El-Sayed, 2009; Rockoff, 2015). For a pharmaceutical company, transitioning to new biotechnology research frameworks means a loss of between 80% and 100% prior knowledge (Rothaermel, 2001). Thus, biopharmaceutical companies have been acquiring the necessary knowledge and intermediate products (patents, technologies, skills) from biotech firms through alliances and acquisitions (Powell et al., 1996; Al-Laham et al., 2008).

Small biotechnology firms have promising novel intellectual property. However, their dream of becoming a vertically integrated "pharma-like" company slams against their inability to conduct capital intensive downstream value chain activities such as conducting clinical trials, managing the regulatory approval process and finally commercializing the product. Thus, many new biopharmaceutical firms are actually founded with the specific intent of generating early stage drug discovery and development and then being sold, sooner or later, to large corporations (Arora and Gambardella, 1990). Thus, in the last decades researchers have observed a large number of acquisitions in the biopharmaceutical industry (Higgins and Rodriguez, 2006; Danzon et al., 2007). This trend is not yet exhausted - a recent IMAP report (IMAP, 2014) indicates that for 2013, there were 615 announced and/or closed transactions, worth US$ 100 billion - an increase of 34% with respect to 2012.

Our investigation is based on secondary data collected from the *BioWorld* database, an online information service providing daily news and analysis, stock indices, company coverage, regulatory and patent reports, and other information in the biopharmaceutical industry (Al-Laham et al., 2008; Birch, 2008). We collected data about any possible biopharmaceutical company in the dataset from the years 2001-2010. We have excluded from our dataset those firms that either went out of business or went through a partial acquisition during the period of observation. Thus, our final dataset consists of 2083 firms. 441 (21%) of those firms were completely acquired in the observed period 2001-2010, while the rest were still independent.

Variable definitions and operationalization

Dependent and independent variables

The dependent variable, Acq_i, is a dummy variable taking the value of 1 if the firm *i* was acquired in the period 2001-2010, 0 otherwise.

As for our explanatory variables, we built the network of inter-firm agreements of the biopharmaceutical firms for each year *t* from 2001-2010. Inter-firm agreements consist of any kind of inter-organizational relationships (unilateral contracts, bilateral alliances, minor equity alliances, joint ventures, mergers and acquisitions) recorded and collected from the *BioWorld* database. We constructed for each year, a network represented by a square matrix $\mathbf{A^t}(n^t \text{ x } n^t)$ where n^t is the number of firms involved in the inter-firm agreements in the year *t*. The generic element of the matrix $\mathbf{A^t}$, a_{ij}^t, is equal to 1, if firms *i* and *j* are involved in an agreement in the year *t*, 0 otherwise.

The *degree centrality* measure captures the number of direct ties connected to the ego firm and it is the most common measure of direct ties centrality in SC literature (Ahuja, 2000; Koka and Prescott, 2002; Salman and Saives, 2005; Wu, 2008; Vanhaverbeke et al., 2012). Thus, as a measure of direct ties centrality of a firm *i* we have calculated the average degree, Dgr_i, of the firm *i* in the years before the acquisition, if the firm has been acquired, or in 2010, in cases the firm remains independent. Thus, this variable is computed as $Dgr_i = \frac{\sum_{t=2001}^{T} Dgr_i^t}{T-2000}$, where Dgr_i^t is the number of different ties (agreements) the firm *i* has at time *t*, and *T* is the year before the acquisition of *i* if the firm has been acquired, or is equal to 2010 if the firm remains independent.

In order to take account of the prominence of the firm in its ego-network, we employed the *eigenvector centrality* measure (Bonacich, 1987; Ahuja, 2000; Koka and Prescott, 2002; Al-Laham et al., 2008). Eigenvector centrality refers to the extent to which a firm's centrality depends on the centrality of the firms to which it is tied to. Hence, a firm has a high value of eigenvector centrality if it is connected to many actors who are themselves connected to many actors. The eigenvector centrality measure has been commonly associated with a firm's prominence by several SC scholars

(Shipilov and Li, 2006; Koka and Prescott, 2008; Ozmel et al., 2013). To evaluate the eigenvector centrality of a firm at time *t*, Eig_i^t, we use the “Eigenvector” routine implemented in UCINET VI (Borgatti et al., 2002) applied at the year *t* matrix $\mathbf{A^t}$. Again we compute the average eigenvector centrality, Eig_i, as the average of Eig_i^t at the year before the acquisition if the firm has been acquired, or at the year 2010, in case it has not been acquired, i.e. $Eig_i = \frac{\sum_{t=2001}^{T} Eig_i^t}{T-2000}$, *T* being the year before the acquisition (if the firm is acquired) or 2010 if not. Because of the high dispersion of this variable, we have computed the natural logarithm of Eig_i, so our actual independent variable is $LnEig_i$.

Control variables

We have included many other factors that may influence the likelihood that a biopharmaceutical firm’s acquisition. First, we control for the *Age* of the firm at the year before its acquisition or at 2010 (if not acquired). The firm’s age is an important determinant of a firm's survival probability because older firms have greater market experience and they are less likely to be acquired (Evans, 1987; Pennings et al., 1998). Second, we control for the nationality of the firm. Our dataset consists of both USA biopharmaceutical firms (57,7%) and non-US firms (42,3%). The American biopharmaceutical industry is the most globally developed (Higgins and Rodriguez, 2006; Danzon et al., 2007) and so we expect USA biopharmaceutical companies to have a greater chance to be acquired. Thus, we include the variable nationality (*Nat*) as a dummy taking value 1, if the firm is an American one, 0 otherwise. Third, the number of products launched by the firm can also influence the likelihood of its acquisition. Indeed, a product is a signal that the firm has successfully integrated the downstream value chain with the abilities needed to develop new drugs (Billitteri et al., 2013). Furthermore, biopharmaceutical firms with launched products are more likely to have products under development in their pipeline, and therefore represent a possible target for pharmaceutical firms, in need of filling their own product pipeline (Higgins and Rodriguez, 2006; Danzon et al., 2007). Thus, we include a count measure of new products launched by each firm from 2001 until the year before the acquisition or at 2010 (if the firm remains independent). This information was retrieved from the product section of *BioWorld.* We included the logarithm of the number of products, *LnProd*, as the control variable. Fourth, the number of previous collaborations is one of the most significant drivers of acquisitions (Gulati, 1995; Gulati, 1998; Hagedoorn et al., 2006). Thus, we also control for the number of previous collaborations (*PrevColl*) the acquired firm had with the acquiring firm. Fifth, we also controlled for the *size* of the firm. Larger firms are less likely to be acquired because of the inhibitive financial resources needed and the potentially high level of risk involved. We measure the size of each company by the number of the firm's employees (Powell, 1997). Since we dealt with both public and private companies, it was not easy to find out the exact number of employees of all the firms. Thus, we collected employees' data in the year of the firm's acquisition or at 2010, if not acquired, by using a categorical variable according to the intervals reported in Table 1. Size data was collected from K10-reports for public firms and from several other web resources, such as LinkedIn, for other firms.

Sixth, IPOs may also influence the probability of a firm to be acquired. We operationalized *IPO* as a variable equal to 1 where the firm went through an Initial Public Offering before the acquisition or up to 2010, 0 otherwise. We gathered this information from the IPO section of *BioWorld* database. We can expect both a positive or negative impact of this variable, respectively depending on whether the IPO works as a signal (Brennan and Franks, 1997; Field, 1999; Jain and Kini, 1999) or mainly as a source of resources needed to resist possible acquisitions (Field, 1999; Field and Karpoff, 2002; Hovakimian and Hutton, 2010).

We also control for the number of patents and its square. Indeed, literature is quite unanimous in considering patents as a signal of quality for technology firms (Baum and Silverman, 2004; Hsu and Ziedonis, 2008 and 2013). Patents represent valuable assets that other firms may be interested in capturing through an acquisition (Ali-Yrkkö et al, 2005). Thus, patents are positively related to acquisition probabilities (Long, 2002). However, patents may also be a source of revenue that may contribute to the growth of young start-ups (Helmers and Rogers, 2011). Especially in high-tech industries, many firms engage in producing and selling patents to the downstream knowledge value chain (Pisano, 1990; Powell and Brantley, 1992; Lerner, 1995; Powell et al., 1996; Mazzola et al., 2015) obtaining a level of cash needed to resist to possible acquisitions (Wagner and Cockburn, 2010). Therefore, patents may have an inverted U-shaped impact on the likelihood to be acquired. We collected the number of patents developed by the firm from 2001 to the year before its acquisition or at 2010 (if not acquired) from the United State Patent and Trademark Office (USPTO) database. Because of the high dispersion of this variable, we use the natural logarithm of the patent number, *LnPat*, and its square, *LnPatSqr*.

Finally, we attempted to control for the year of acquisition in order to check for a possible influence of acquisition trends in some particular years. However, controlling for the years introduces a perfect collinearity with the dependent variable just because each year variable would predict a perfect success (a value of 1) of the dependent variable. Thus, we have analyzed year specific behaviors in order to locate if some years could introduce some singularity in our data. Figure 2 shows how acquisitions, in the observed years (2001-2010), present a clear growing trend, but no years seem to explain acquisitions better than others.

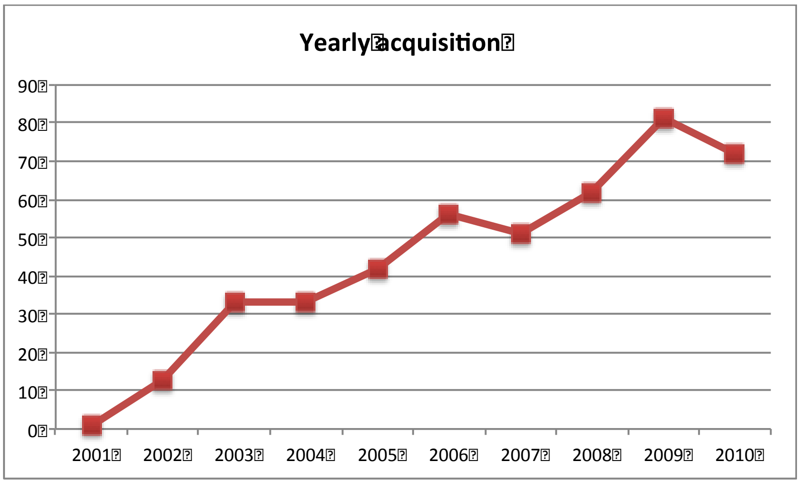

Figure 2. Number of acquisitions in the observed period (2001-2010)

FINDINGS

Table 2 provides the descriptive statistics and the correlations between all the variables. All the correlation coefficients between the independent variables are quite low. To assess the potential threat of collinearity, we estimated the variance inflation factors (VIFs) and found that no variable had a VIF greater than 2.56, which is below the recommended ceiling of 10 (Stevens, 1992).

---- Insert Table 1 and 2 about here ----

Since the dependent variable is dichotomous, we can run a probit or logit regression (Hoetker, 2007). The choice between logit and probit models is largely one of convenience and convention since both the models tend to produce very similar predictions and the results are generally indistinguishable (Long, 1997). In this paper, we used a probit estimation. Table 3 provides an overview of the results.

The baseline model (model 1) shows the effects of control variables. Models 2 and 3 test, respectively, for the main (*Dgr*) and squared (*DgrSqr*) effect of the degree centrality. The main effect of eigenvector centrality (*LnEig*) is reported in model 4, while the square effect is reported in model 5 (*LnEigSqr*). Model 6 puts together the variables under investigation, *Dgr* and *LnEig* and their squared terms. Model 7 tests the interaction between *Dgr* and *IPO* and *DgrSqr* and *IPO*, while model 8 tests the interaction between *LnEig* and *IPO* and *LnEigSqr* and *IPO*. The model fitting increases each time the explanatory variables, both plain and squared, and the interaction terms are introduced.

--- Insert Table 3 about here ---

All the control variables, except *LnProd*, are significant (model 1). The coefficient of *Age* is negative, thus, as expected, older firms are less likely to be acquired. The coefficient of *Nat* is positive, meaning that USA firms are more likely to be acquired. Previous collaborations

(*PrevColl*), as largely expected, have a positive impact on the likelihood to be acquired. The *size* of the firm is also significant. Indeed, where the category micro-firms (MI) is assumed as a baseline, the results show that firms having smaller dimensions, until the category very large (VL), have a positive and significant effect on the probability to be acquired. In accordance with the stream of literature that considers IPO as a source of resources, we get a negative and significant impact of the *IPO* on the likelihood to be acquired. Finally, in line with our conjecture, patents have an inverted U-shaped effect on the likelihood to be acquired.

In H1 we argued that direct ties have an inverted U-shaped effect on the firm's probability to be acquired; the coefficient of *Dgr* is positive and significant in model 2, while the coefficient of *DgrSqr* is negative and significant in model 3, thus supporting H1. H2 argued that prominence, measured through the firm's eigenvector centrality, has an inverted U-shaped effect on the firm's probability to be acquired; the coefficient of *LnEig* is positive and significant in model 4, while the coefficient of *LnEigSqr* is negative and significant in model 5, thus supporting H2. Moreover, H1 and H2 received further confirmation from model 6 where all the explanatory variables, *Dgr*, *DgrSqr*, *LnEig* and *LnEigSqr*, continue to be highly significant and with the expected signs.

Figures 3a and 3b is a graphical representation of the results concerning H1 and H2. An inverted U-shaped relationship exists if Y first increases with X at a decreasing rate to reach a maximum, after which Y decreases at an increasing rate. The point at which the curve attains its maximum is the "turning point", and it needs to be located well within the data range (Lind and Mehlum, 2010). We tested this assumption following the procedure stated in the recent paper by Haans et al., (2015) on the use of U-shaped relations in strategic management literature and affirmed our results as shown in Figures 3a and 3b.

Models 7 and 8 exhibit a negative, and significant, linear interaction between *IPO* and respectively *Dgr* and *LnEig*. The interaction between *DgrSqr* and *IPO* in model 7 is not significant, while the interaction between *IPO* and *LnEigSqr* is significant and positive. These results confirm, only for *LnEig*, our prediction of H3 that an IPO makes the relation between prominence and the probability of being acquired weaker, when prominence does not assume strong values. Indeed, as clearly shown in Figure 4, for moderate levels of eigenvector centrality, the green dots are significantly under the red ones, meaning that when the firm goes through an IPO the probability to be acquired is significantly lower than when it doesn't go through an IPO. However, when the eigenvector centrality reaches high levels the negative moderation effect of the IPO is attenuated as predicted by H3.

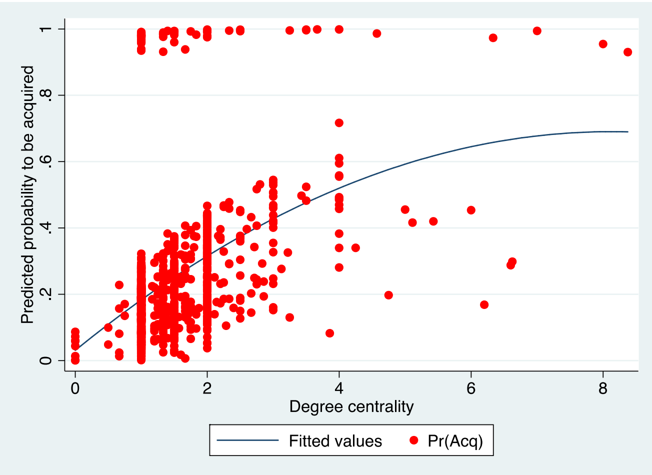

Figure 3a. Probability to be acquired vs. Degree centrality

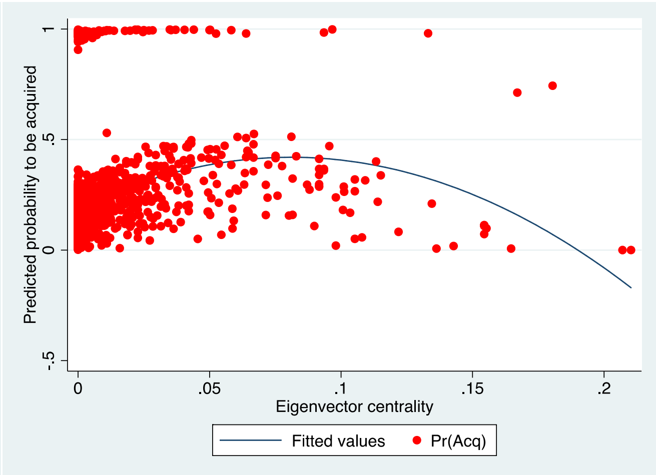

Figure 3b. Probability to be acquired vs. Eigenvector centrality

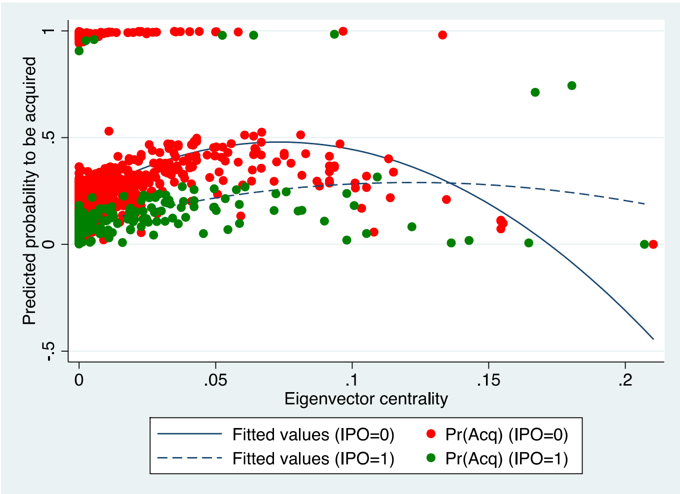

Figure 4. IPO effects on the probability to be acquired vs. Eigenvector centrality

DISCUSSION AND CONCLUSION

Our study makes three contributions to social capital literature. First, to the best of our knowledge, this is the first research that addresses the impact of a firm's network positions on its likelihood to be acquired. Previous studies in SC literature have examined the firm's survival (Brüderl, and

Preisendörfer, 1996; Mitchell and Singh, 1996; Uzzi, 1996; Watson, 2007), the firm's dissolution (Pennings et al., 1998), and the firm's propensity to make acquisitions or mergers (Haunschild, 1993; Hoang, 1997; Lin et al., 2009; Yang et al., 2011). Our study align with prior findings that show a positive impact of social capital on firms' survival (e.g. Brüderl and Preisendörfer, 1996). Our study extends previous research and shows how and why a firm’s direct ties and prominence provide a signal that catalyses its acquisition. We explain the mechanism through which this happens - i.e. how the *visibility-enhancing* effect of direct ties is subsequently dampened by the *network resources* effect resulting in an overall inverted U-shaped relation. Similarly, the *quality signalling* effect of prominence is subsequently reversed by *network-status* resulting in an overall inverted U-shaped relation.

Although these two centrality features exhibit the same behaviours, as Figures 3a and 3b and a comparison of their standardized coefficients shows, the influence of the eigenvector centrality (a standardized coefficient of -0.218) is much stronger than the degree centrality one (a standardized coefficient of -0.088) in decreasing a firm’s probability to be acquired. This result is quite interesting considering that, for instance, both Ahuja (2000) and Salman and Saives (2005) do not find appreciable differences between direct centrality and eigenvector centrality in driving innovation outputs such as patents. Our study seems to indicate that, at least with respect to acquisition probabilities, they have different strengths. To explain this finding, we suggest that on the one hand direct ties expose the firm directly to partners that may be possible buyers; thus, even if the firm gains access to resources through its network, its exposure to possible buyers has a relatively more telling effect. On the other hand, highly prominent firms may enjoy advantages of status and are less exposed to effects of direct relations. Another reason could be that the *status effect* is just stronger than the *resource effect* in protecting the firm from being acquired. For instance, the benefits from network status extend to a wider portion of the network, while access to resources is largely provided by direct ties that are limited to the neighborhood of the ego firm. The different explanations of the findings call for deeper research.

These results have important managerial implications - at least in the biopharmaceutical context. Direct ties and prominence are a double-edged sword. A firm's inter-firm network position can enhance its visibility and signal its quality and thus improve its likelihood of being acquired. At the same time, as firms achieve strong centrality positions, it is likely that the network also provides sufficient resources and status to assure the independence of the firms. Furthermore, as previously mentioned, prominence seems to provide a better defence against acquisitions.

Second, our study enhances SC literature by including social capital as a source of valuable signals for firms. Indeed, while SC literature has considered relational embeddedness as a source of valuable signals (e.g. Gulati and Higgins, 2003), only the recent study by Ozmel et al. (2013) examines structural embeddedness features as a source of signals for a firm. However, Ozmel et al (2013) limited their analysis to one dimension of structural embeddedness – the firm's prominence, i.e. the eigenvector centrality feature. Our study builds on their work and shows that direct ties also signal the value of the focal firm.

Furthermore, our work shows how even moderate values of direct ties and network prominence are able to provide a visibility-enhancing signal. The signalling effect of a firm's network position has an asymptotic behaviour whose marginal impact on the likelihood of its acquisition progressively decreases the more the firm's two network positions strengthen. Moreover, our study suggests a dynamic of the signalling effect of network positions. At moderate levels of direct ties and network prominence the firm acquires visibility and signals its quality. However, both visibility and quality signals marginally decrease in their importance, at least in increasing the firm's acquisition probability, once they reach stronger values.

Finally, by analysing the interactions between a firm's network positions and whether it undertakes an IPO or not, we contribute to a better understanding of the impact of multiple signals on the firm's likelihood to be acquired. Our results show that an IPO subsumes the signalling impact of prominence and weakens its effect on the firm's probability to be acquired. This result adds new knowledge to the literature that places IPOs in relation to acquisition probabilities. In line with literature on IPO as a source of resources and status that places the firm in a better position to resist acquisitions (e.g. Field, 1999), we show how for moderate levels of prominence, an IPO acts as a perfect substitute of the visibility enhancing and quality signals provided by the network position. However, higher values of prominence signal the status of the firm (Brennan and Franks, 1997; Jain and Kini, 1999), and allow the firm to stand out from the crowd of IPO-firms and thereby improve the likelihood to be acquired. Direct centrality though, even when it directly exposes the firm to possible buyers (H3), does not seem to provide complementing signals for either IPO or non-IPO firms. Of course, these results have significant managerial implications. First, IPO events completely change the impact of direct ties and prominence on a firm's likelihood to be acquired, indicating that managers need to re-consider the impact of their network strategies when dealing with an IPO. Second, direct ties and prominence have slightly different interactions, with prominence the only variable that is really more involved in interaction with IPO.

This study has some limitations that in turn present future opportunities for development of this work. First, we focus on direct ties and prominence as structural embeddedness network features; however, bridging structural holes are a network feature that has raised several research contributions among SC scholars (e.g. Ahuja, 2000; Zaheer and Bell, 2005). Thus, understanding the effect of structural holes on the likelihood to be acquired would complete the theoretical framework. Second, our study did not consider a relational perspective (i.e. the typology of the relation) of the inter-firm agreements as this issue has been previously addressed in alliance literature (e.g. Haunschild, 1994; Afuah, 2001; Anderson et al., 2001). Our focus was on network positioning. However, further studies can investigate how relational and network position influence each other with respect to acquisition probability. Third, we did not consider the level of success of an IPO. A much better operationalization of the IPO variable could offer a more comprehensive understanding of the quality of the IPO signal. Finally, because the intention is to analyse the relationship between the firm's network position in its inter-firm network and the probability of being acquired, this study focuses on the biopharmaceutical industry in which inter-firm networks are a quite common phenomenon (Rothaermel, 2001) and the company sale is an exit strategy (Arora and Gambardella, 1990). Thus, although this approach is appropriate, it would be unwise to generalize the findings too broadly to other industries and cultural contexts.

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Size categories	**Employees intervals**
Micro-Firms, MI	1-10
Very Small firms, VS	11-50
Small Firms, SM	51-200
Medium Firms, ME	201-500
Large firms, LA	501-1000
Very Large firms, VL	1001-5000
Corporation, CO	5000-10000
Large Corporation, LC	>10000

Table 1. Firm size categories and intervals

	Mean	SD	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1. Acq	.212	.408	0	1	1.00																
2. Age	18.41	24.0	0	342	-0.08	1.00															
3. Nat	.5760	.494	0	1	0.07	-0.08	1.00														
4. LnProd	.0372	.229	0	3.68	0.02	0.10	0.06	1.00													
5. Prevcoll	.0412	199	0	1	0.38	-0.04	0.01	0.04	1.00												
6. MI	.119	.324	0	1	-0.06	-0.09	0.04	-0.05	-0.00	1.00											
7. VS	.345	.475	0	1	-0.01	-0.19	-0.02	-0.093	-0.02	-0.26	1.00										
8. SM	.299	.458	0	1	0.08	-0.11	-0.00	-0.02	0.00	-0.24	-0.47	1.00									
9. ME	.073	.260	0	1	0.02	0.01	0.03	0.03	0.07	-0.10	-0.20	-0.18	1.00								
10. LA	.040	.197	0	1	-0.01	0.07	0.01	-0.00	-0.01	-0.07	-0.14	-0.13	-0.05	1.00							
11. VL	.050	.219	0	1	-0.01	0.19	-0.00	0.06	0.00	-0.08	-0.16	-0.15	-0.06	-0.04	1.00						
12. CO	.020	.140	0	1	-0.01	0.13	-0.04	0.08	0.00	-0.05	-0.10	-0.09	-0.04	-0.02	-0.03	1.00					
13. LC	.049	.216	0	1	-0.04	0.45	-0.01	0.18	-0.02	-0.08	-0.16	-0.14	-0.06	-0.04	-0.05	-0.03	1.00				
14. IPO	.211	.408	0	1	-0.13	0.17	-0.01	0.13	-0.06	-0.04	-0.08	-0.03	0.03	0.05	0.06	0.07	0.12	1.00			
15. LnPat	1.46	1.67	0	8.61	-0.03	0.40	0.08	0.23	0.00	-0.17	-0.24	-0.02	0.07	0.08	0.18	0.16	0.40	0.28	1.00		
16. Dgr	.007	.020	0	0.22	0.09	0.11	0.02	0.13	0.09	-0.07	-0.06	-0.01	0.03	0.03	0.04	-0.03	0.18	0.06	0.21	1.00	
17. LnEig	1.23	.639	0	0.837	0.17	-0.03	0.08	0.23	0.16	-0.07	-0.09	0.00	0.07	0.07	0.09	0.00	0.03	0.09	0.21	0.35	1.00

Table 2. Descriptive statistics and correlation matrix

Probability to be acquired - Probit models								
	M1	***M2***	***M3***	***M4***	***M5***	***M6***	***M7***	***M8***
Age	-0.00477^{+}	-0.00388	-0.00415^{+}	-0.00471^{+}	-0.00430^{+}	-0.00379	-0.00444^{+}	-0.00447^{+}
	(0.00252)	(0.00241)	(0.00245)	(0.00251)	(0.00245)	(0.00239)	(0.00248)	(0.00250)
Nat	0.221**	0.202**	0.201**	0.217**	0.203**	0.189**	0.202**	0.200**
	(0.0692)	(0.0698)	(0.0700)	(0.0694)	(0.0697)	(0.0702)	(0.0699)	(0.0698)
LnProd	0.235	0.0971	0.163	0.220	0.247^{+}	0.185	0.179	0.238
	(0.148)	(0.165)	(0.149)	(0.152)	(0.141)	(0.147)	(0.155)	(0.148)
PrevColl	2.967***	2.894***	2.918***	2.914***	2.967***	2.930***	2.931***	2.954***
	(0.289)	(0.289)	(0.296)	(0.292)	(0.333)	(0.328)	(0.300)	(0.295)
VS	0.305*	0.285*	0.284*	0.294*	0.272*	0.263*	0.284*	0.261*
	(0.123)	(0.123)	(0.124)	(0.123)	(0.124)	(0.124)	(0.124)	(0.124)
SM	0.510***	0.474***	0.466***	0.501***	0.473***	0.444***	0.462***	0.460***
	(0.125)	(0.125)	(0.126)	(0.125)	(0.126)	(0.126)	(0.126)	(0.126)
ME	0.286^{+}	0.236	0.230	0.276	0.242	0.206	0.222	0.246
	(0.174)	(0.175)	(0.175)	(0.175)	(0.177)	(0.177)	(0.175)	(0.175)
LA	0.378^{+}	0.266	0.273	0.353^{+}	0.336	0.256	0.278	0.318
	(0.206)	(0.212)	(0.211)	(0.208)	(0.209)	(0.214)	(0.212)	(0.209)
VL	0.338^{+}	0.244	0.258	0.323	0.288	0.228	0.262	0.270
	(0.202)	(0.206)	(0.204)	(0.201)	(0.200)	(0.203)	(0.205)	(0.201)
CO	0.365	0.368	0.355	0.398	0.391	0.373	0.369	0.385
	(0.297)	(0.299)	(0.303)	(0.296)	(0.295)	(0.301)	(0.299)	(0.293)
LC	0.396	0.401^{+}	0.391	0.336	0.344	0.367	0.373	0.335
	(0.247)	(0.242)	(0.241)	(0.249)	(0.244)	(0.239)	(0.243)	(0.248)
IPO	-0.539***	-0.560***	-0.566***	-0.539***	-0.540***	-0.564***	-0.550***	-0.439***
	(0.0986)	(0.101)	(0.101)	(0.0994)	(0.0998)	(0.102)	(0.0998)	(0.104)
LnPat	0.0621*	0.0501^{+}	0.0437	0.0531^{+}	0.0443	0.0339	0.0435	0.0446
	(0.0300)	(0.0304)	(0.0305)	(0.0300)	(0.0301)	(0.0306)	(0.0305)	(0.0302)
PatSqr	-0.0737*	-0.0916*	-0.0811*	-0.0750*	-0.0779*	-0.0860*	-0.0734*	-0.0746*
	(0.0334)	(0.0362)	(0.0354)	(0.0338)	(0.0345)	(0.0362)	(0.0352)	(0.0345)
Dgr		0.302***	0.455***			0.373***	0.538***	
		(0.0574)	(0.0833)			(0.0877)	(0.104)	
DgrSqr			-0.0274**			-0.0195^{+}	-0.0339*	
			(0.00919)			(0.0108)	(0.0154)	
LnEig				4.738**	16.46***	12.68***		21.49***
				(1.540)	(3.445)	(3.707)		(4.397)
LnEigSqr					-0.0679***	-0.0574**		-0.0936**
					(0.0181)	(0.0214)		(0.0295)
Ipo x Dgr							-0.264^{+}	
							(0.136)	
Ipo x DgrSqr							0.0274	
							(0.0211)	
Ipo x Eig								-21.09*
								(9.390)
Ipo x LnEigSqr								0.0914*
								(0.0406)
Cons	-1.255***	-1.565***	-1.727***	-1.264***	-1.259***	-1.642***	-1.825***	-1.265***

	(0.122)	(0.135)	(0.151)	(0.122)	(0.122)	(0.154)	(0.167)	(0.122)
Wald ald	189.56	214.09	219.43	192.09	173.84	202.64	237.91	219.87
Pseudo R2	0.1588	0.1718	0.1740	0.1626	0.1697	0.1799	0.1759	0.1727
Log_pseudo likelihood	-905.66	-891.61	-889.23	-901.54	-893.89	-882.93	-887.17	-890.63
N	2083	2083	2083	2083	2083	2083	2083	2083

Standard errors in parentheses $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Results of the probit analysis