

DISCUSSION

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Hiring New Key Inventors to Improve Firms' Post-M&A Inventive Output

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Abstract

Although merger and acquisitions (M&As) are acknowledged as an important means to access innovative assets and know-how, firms' inventive output often declines in the post-M&A period. Financial, managerial and organizational constraints related to the M&A event contribute to inventive output declines and inventors' departure. Prior literature treats the acquiring firm as a passive observer of invention declines. This study argues that acquiring firms can take measures by hiring new key inventors. We show that the hiring of new key inventors in the post-M&A period can counteract invention declines in two ways. First, these newly hired inventors are associated with an increase of corporate inventive output after the M&A. Second, they are also associated with an improved inventive output of inventors already working for the acquiring firm. These results suggest that an appropriate hiring policy can counteract declining inventive output of firms in the aftermath of M&As.

Keywords: M&A, post-M&A inventive output, key inventors, KBV

JEL: O34, O32, G34

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1. INTRODUCTION

Mergers and acquisitions (M&As) are an important means by which firms can access technological assets and know-how held by the acquisition target (Arora et al., 2001; Capron et al., 1998; Cassiman et al., 2005; Granstrand and Sjolander, 1990; Graebner, 2004). M&As grant access to technological competencies and capabilities (Chaudhuri and Tabrizi, 1999; Granstrand and Sjolander, 1990) and to essential intellectual property rights (Grimpe and Hussinger, 2008; 2014), therewith complementing or extending the technology portfolio of the acquiring firm (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloudt et al., 2006).

The expected benefits of M&As for innovation notwithstanding, most empirical studies report innovation output declines in the post-M&A years (Hitt et al., 1998; see Veugelers, 2006, for a survey) due to a shift of managerial attention from daily business activities and innovation to the M&A event (Hitt et al., 1990), M&A-induced financial constraints (Hitt et al., 1996) or organizational and cultural differences between target and acquiring firm (Cartwright and Schoenberg, 2006; Chatterjee, 1986; Hitt et al., 1991). M&As and their organizational implications constitute a disruption of firms' routines which creates uncertainties regarding job security and task definitions and therewith induce demotivation and cognitive barriers to knowledge exploitation (Jensen and Szulanski, 2004; Minbaeva et al., 2003). Inventors react with departure or decreased innovative output (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006).

Prior studies on the effects of M&As on innovation output treat acquiring firms as passive observers that need to accept inventors' departure and inventive output declines of incumbent inventors. We argue that acquiring firms can take measures to counteract inventive output declines, namely hiring new key inventors (Aggarwal and Hsu, 2012). Drawing from the knowledge-based view (KBV), we argue that the hiring of new key inventors has two effects on post-M&A inventive output. First, newly hired key inventors can constitute novel and superior sources of knowledge, strengthening the knowledge base of the acquiring firm. Acquiring firms can leverage the knowledge of newly hired key inventors and use it as an input on their own innovation process (Puranam and Srikant, 2007). Hence, the acquired knowledge of the newly hired key inventors is expected to have a direct positive effect on the inventive output of the acquiring firm after the M&A. Second, we derive from KBV and the theory of organizational

learning that there is an important indirect effect in the sense that the newly hired talents improve the output of incumbent inventors. The underlying mechanism is social interactions between new key and incumbent inventors which offer the opportunity of knowledge recombination (Nerkar and Paruchuri, 2005) and knowledge spillovers (Zucker and Darby, 1997).

Our empirical results show that indeed the hiring of key inventors is associated with important direct and indirect effects on post-M&A inventive output. These results suggest that an appropriate human capital strategy around the M&A event can help avoiding a temporary decrease in inventive output in the post-M&A period. Our findings have important practical implications for executives being involved in an M&A, suggesting a proactive human resource strategy including the hiring of external key inventors.

2. THEORY DEVELOPMENT & HYPOTHESES

Knowledge creation within the corporate context

The knowledge-based view of the firm (KBV) recognizes knowledge as the most important strategic resource for the firm (Grant, 1996), pointing out the essential role of knowledge for value creation and for achieving a competitive advantage (Barney, 1991; Felin and Hesterly, 2007). Individuals are viewed as the sources of knowledge and talent, while the role of organizations is to facilitate knowledge exploitation (Cyert and March, 1983; Grant, 1996). Firms present a platform that enables individuals to interact and to exchange knowledge (Grant, 1996; Tsoukas and Mylonopoulos, 2004). The process of knowledge exploitation is facilitated by the context the firm provides and its organizational routines within which knowledge workers carry out their tasks and develop their own routines (Cyert and March, 1963; Nelson and Winter, 1982). Routines provide guidance for individuals within an organization and facilitate coordination (Kapoor and Lim, 2007; Winter, 1986) through formal and informal procedures and communication (Szulanski, 2000). Even though routines can be simple sequences, they are able to support complex patterns of interaction between individuals (Grant, 1996) and to store knowledge and information (Darr et al., 1995), making them key in the knowledge production process (Levitt and March, 1988).

The impact of M&As on invention output

Prior studies have largely documented the negative impact of M&As on corporate innovation (e.g. Cassiman et al., 2005; Hitt et al., 1998; Prichett, 1985; Ravenscraft and Scherer, 1987; see Veugelers, 2006, for a survey of the literature). These innovation declines can be traced back to several firm-level factors. First, managerial attention shifts away from daily activities and R&D to managing the M&A event (Hitt et al., 1990). Second, from a financial point of view, the pressure imposed by the acquisition investment (Hitt et al., 1991; Miller, 1990) and the introduction of cost-saving programs aimed at eliminating duplicative research efforts (Lengnick-Hall, 1991; Veugelers, 2006) may induce cutbacks of R&D budgets. Finally, insufficiently planned and poorly executed post-M&A integration has shown to hamper inventors' output significantly (e.g. Haspeslagh and Jemison, 1991; Jemison and Sitkin, 1986; Pritchett, 1985). The negative effects are stronger in the presence of cultural and organizational differences between acquirer and target as well as low technological proximity (Ahuja and Katila, 2001; Cartwright and Schoenberg, 2006; Cassiman et al., 2005; Cloudt et al., 2006; Ernst and Vitt, 2000; Junni et al., 2015) and less strong if the acquiring firm has a certain level of absorptive capacity (Hussinger, 2012).

These firm-level factors affect the output of individual inventors by impeding inventors' and organizational routines. The post-M&A integration process typically implies strategic reconfigurations and restructuring activities (Karim and Mitchell, 2000), higher fluctuation rates of personnel and changes in job definitions and positions (Ernst and Vitt, 2000; Walsh, 1988) that may create a sense of dislocation and even trauma for the individual inventor (Cartwright and Cooper, 1993; Paruchuri et al., 2006). Inventors within the acquiring firm become concerned about the future strategic direction of the firm and the implications for their tasks, their employment safety, and the future definition of their position within the firm (Souder and Chakrabarti, 1984). Psychological reactions generated by the disruptive nature of the M&A event limit the cognitive ability of inventors and their capability to process new information (Fugate et al., 2008). Inventors' attention is focused on coping with the disruptive situation rather than processing work-related information (Fugate et al., 2008; Staw et al., 1981). On the one hand, this creates a cognitive barrier to the exploitation of the inventors' knowledge (Jensen and Szulanski, 2004; Minbaeva et al., 2003), which impedes the individuals' ability to process new information and to exploit existing knowledge which is crucial for their invention output. On the other hand,

the accompanying task uncertainty and a probable job uncertainty can result in the departure of R&D employees (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006). Thus, since firms' output is composed of the contributions of the individual inventors, the combined effect of productivity declines of the individual inventors that remain within the firm and the departure of inventors negatively impact the firms' overall inventive output in the post-M&A period.

Hiring new key inventors as a remedy for post-M&A productivity declines

While providing ample evidence on post-M&A innovation output declines and their causes (e.g. Ernst and Vitt, 2000; Hitt et al., 1991; 1996; Kapoor and Lim, 2007; Paruchuri et al., 2006; Ravenscraft and Scherer, 1987), previous literature is silent about possible remedies that can be employed by the acquiring firm. We suggest the hiring of key inventors as one specific mean acquiring firms can take in order to counteract post-M&A inventive output declines.

The mobility of inventors represents an effective transfer of knowledge across organizations as well as a channel for knowledge diffusion (Almeida and Kogut, 1999; Hoisl, 2007; Song et al., 2003). Inventors accumulate both tacit and explicit knowledge through their personal experience, by observing and working with their colleagues or through informal that they carry to their new employer interactions (Nonaka, 1994; Palomeras and Melero, 2010; Rosen, 1972). They also bring along key routines and relational capital that help recipient firms to change existing technological trajectories and to benefit from knowledge spillovers (Mawdsley and Somaya, 2016; Song et al., 2003; Rosenkopf and Almeida, 2003; Tzabbar, 2009).

Individual inventors, however, have been shown to be heterogeneous in terms of the knowledge they possess (Zucker and Darby, 1995; Zucker et al., 1998), with their output distribution being highly skewed (Lotka, 1926; Narin and Breitzman, 1995; Price, 1965). Within each technological domain and each organizational context, there are some key inventors that are crucial for the process of invention creation due to their superior technical knowledge and expertise (French and Raven, 1959), but also because of the tacit knowledge they carry (Hess and Rothaermel, 2011; Zucker et al., 2002).

We argue that acquiring firms can hire new key inventors from outside the merged firm with superior past inventive output as compared to most incumbent inventors to proactively counteract

inventive output declines after M&As. Newly hired key inventors are expected to positively contribute to the process of organizational learning and knowledge creation within their new environment due to the knowledge they carry, their experience, skills endowment, and talent. The hiring of key inventors will provide the acquiring firms with access to these skills, competencies, and experiences (Rao and Drazin, 2002) and also to the knowledge gathered at their former employer (Barney, 1991). As an additional and new input to the firm's knowledge production process, we anticipate the hiring of new key inventors to have a positive effect on the firm's invention output.

Hypothesis 1. Newly hired key inventors are positively associated with the acquiring firm's post-M&A inventive output (direct effect).

Newly hired key inventors are also expected to have a positive impact on the inventive output of incumbent inventors at the acquiring firm, who are often found to experience an invention productivity decline after an M&A. KBV research of organizational learning has explored the mechanism of internal learning and transmission of information through members of an organization. Levitt and March (1988) explore different processes of knowledge diffusion and point out that transmission of information takes place through inter-personal contacts, somewhat similar to the spread of a disease. Thus, the movement of personnel, which facilitates the contact between incumbent inventors and newly hired inventors, is the main mechanism that facilitates the transmission of knowledge and organizational learning (Biggart, 1977).

This transmission mechanism is documented in the prior empirical literature (e.g., Mas and Moretti, 2009; Paruchuri, 2010; Sacerdote, 2001).¹ These studies argue that social interactions between inventors are an important channel to knowledge recombination (Nerkar and Paruchuri, 2005) and knowledge spillovers (Zucker and Darby, 1997). Since a newly hired key inventor is likely to receive a key position within the acquiring firm she will be in contact with many other inventors within the firm (Kehoe and Tzabbar, 2015; Paruchuri, 2010). Accordingly, the newly hired key inventor has more channels for knowledge dissemination as compared to inventors in less central positions. Given their central network position within the firm (Bonacich, 1987;

¹ Other studies that relate to the influence of key inventors on their colleagues are: (1) Azoulay et al. (2010) who show that the productivity of peers decreases by 5%-8% if a key collaborator dies unexpectedly; (2) Oetl (2012) who finds that the negative effect refers in the first place to the quality of the scientists' output; and (3) Waldinger (2012) who explores the long-lasting effects on the quality of recruits of key dismissals in Nazi Germany.

Krackhardt, 1990), we expect that newly hired key inventors can disseminate their knowledge within the organization both fast and effectively.

The arrival of new key inventors can counteract the discouraging effect of the M&A event on the remaining inventors at the acquiring firm. First of all, the hiring of key inventors signals the importance of invention for the firm during the M&A period so that incumbent inventors' uncertainty about their future is reduced. By hiring key inventors, acquiring firms show their commitment to invention which can reduce employees' concerns about their future employment, allowing them to focus more on processing new, innovative information. Second, newly hired key inventors can spur the motivation of inventors at the acquiring firm because inventors have a strong preference to work with higher qualified colleagues (Barabási et al., 2002; Wagner and Leydesdorff, 2005). Third, new key inventors can leverage their position and resource access to reduce task and job insecurity among incumbent inventors as they provide new leadership and strategic direction to their peers (Kehoe and Tzabbar, 2015; Paruchuri, 2010). Key inventors are regarded as innovative leaders with the ability to initiate and lead innovation efforts (Kehoe and Tzabbar, 2015), so that by working with them, incumbent inventors engage in new projects that, given the expertise and productivity of key inventors, are more likely to be successful. Not at least, newly hired key inventors can strengthen the transactive system by closing the gaps that result from inventor departure with positive implications for the incumbent inventors' invention output.

As compared to periods of normal activity, when the hiring of key inventors might create resistance among incumbent colleagues or hamper their productivity (Huckman and Pisano, 2006; Kehoe and Tzabbar, 2015), M&As represent periods of turbulence that involve structural adjustments, and changes in leadership, strategies and long-term orientation of the firm, as well as departure of key personnel (Ernst and Vitt, 2000; Jensen and Szulanski, 2004; Minbaeva et al., 2003). Since new key inventors arrive at a time of turmoil, we believe that their positive effect, as a signal of R&D being taken serious within the merged firm along with the above presented arguments on knowledge transfer, outweighs potential resistance.

Hypothesis 2. Newly hired key inventors are positively associated with the contribution of incumbent inventors to the acquiring firm's post-M&A inventive output (indirect effect).

3. METHODS

Dataset

Our analysis is based on a large, tailor-made dataset set that draws from several different databases. It includes information on all publicly listed U.S. firms involved in M&As over the period 1980-2010 where at least one of the M&A parties is actively involved in invention activities in the sense that it has applied for at least one patent at the United States Patent and Trademark Office (USPTO) since its foundation. Information about the M&A deals was extracted from the database Thomson One Banker provided by Thomson Reuters. We consider only those deals that were completed and which involved majority ownership. The M&A data was linked to firms' financial records which were retrieved from Compustat. The match between the two databases is based on firms' name, state, and the firms' identifiers CUSIP and PERMNO (taken from the Center for Research in Security Prices (CRSP) database).

Information on the patent activity of firms and inventors is taken from the NBER patent database and the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014). Patent information is matched to the firm data using each firm's identifiers and name. Data on the mobility of inventors is taken from the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014).

The resulting sample consists of a panel data set including 1,402 deals, corresponding to firms in 62 different industries over a 31-year period. We keep a 9-year window around the M&A for our analysis of the M&A period (see Ahuja and Katila (2001), and Kapoor and Lim (2007) for similar choices). A 9-year window allows mapping the short time effects of the M&A. A too wide time window bears the risk to attribute output developments which are more distant in terms of time wrongly to the M&A event.

Variables

Dependent Variable

The dependent variable in our model is the firms' inventive output as proxied by the number of granted patents per year of the acquiring firm (e.g. Griliches, 1990; Archibugi, 1992; Cohen and Levin, 1989; Griliches, 1990). We use granted patents and not patent applications because the

former is an indicator of successful invention (Ahuja and Katila, 2001).² We count the granted patent in the application year. The advantage of the application year is that it is close to the actual invention and abstracts from delays that may occur in the patent granting process (Ahuja and Katila, 2001; Ernst, 2001; Trajtenberg, 1990).

After M&A indicator

We use a dummy variable to distinguish the periods before and after the M&A. The variable is equal to zero for the years before the M&A and equal to one on the year in which the M&A occurs and thereafter.

Incumbent Inventors

We use the number of incumbent inventors as a proxy for the stock of knowledge which is the major ingredient to the patent production function (Pakes and Griliches, 1980). Our definition includes those inventors that are working at the M&A firm on year t . We assume that an inventor who patented in year $t-X$ and again in year $t+X$ for the focal firm is also employed at the firm in year t . Due to multicollinearity concerns, we normalize the number of inventors by firms' size.

Departing Inventors

Mobility is defined based on the appearance of inventors on patent documents of different patent applicants. An inventor is defined to move from firm i to firm j when after filing the last patent application with firm i , she starts filing an application with firm j , and no longer with firm i . We measure departing inventors as the ratio of inventors departing the firm at time t over the total number of inventors at time t .

New key inventors

For testing our hypotheses, we generate a variable, *new key inventors*, that is interacted with the *after M&A* dummy variable for testing hypothesis 1 (direct effect), and with the *after M&A* variable and the *incumbent inventor* variable for testing hypothesis 2 (indirect effect).

² Often patent citations are used as a means to account for the "quality" of patents. We refrain from using patent citations as an alternative dependent variable or as a quality adjustment for the patent count variable because the M&A could impact the citation likelihood and rate of the merged firms' patents. For instance, a highly reputed target firm might impact acquirer's citation rate after the M&A.

We define key inventors relative to the quality of the inventors already working at the acquiring firm, as measured by the total number of citations their patents received in the past. Following previous studies on post-M&A inventor output (see e.g. Kapoor and Lim, 2007, and Paruchuri et al., 2006), we apply a relative definition because we are interested in depicting a newly acquired superior knowledge source from the point of view of the acquiring firm.³ In order to account for the fact that knowledge gets outdated over time, we apply a depreciation rate of 15% per year to the inventors' patents (Hall, 1990).

Regarding our specific measure, we identify key inventors as those receiving more patent citations than the top 75% of inventors of the acquiring firm. We define key inventors who are new to the firm as the ratio of key inventors hired by the firm at time t over the total number of inventors at time t in order to avoid multicollinearity issues.

Control variables

We include total assets as a proxy for firm size (Cohen and Levinthal, 1989; Mansfield, 1986; Scherer, 1983). We take the logarithm to account for the skewness of its distribution. Further, we use a set of year dummies in order to control for time trends in corporate patenting. Industry dummies do not explicitly enter our specification because they are time-invariant and hence absorbed by the firm-specific fixed effects that we use.

All independent and control variables are lagged by one year in order to limit endogeneity concerns.

4. EMPIRICAL FINDINGS

Regression results

We employ fixed-effects Poisson regressions with robust standard errors in order to account for the count data nature of the dependent variable and for unobserved firm-specific effects (Wooldridge, 2010).⁴ Table 1 presents the estimation results (see Tables A1 and A2 in Appendix I for descriptive statistics and bivariate correlations).

³ In line with Aggarwal and Hsu (2012), we define newly hired key inventors relative to the majority of inventors that are already working for the firm. Key inventors in their field of technology, as defined by Zucker and Darby (1999; 2001), are rare so that they might not show up frequently in firms involved in M&As.

⁴ We choose fixed-effects Poisson regression over fixed-effects negative binomial (Hausman et al., 1984) because the latter is not a true FE method (see Allison and Waterman, 2002 for a discussion). Since in our paper endogeneity is a concern due to unobserved variables such as

Table 1. FE Poisson regression for firms' patenting output

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.12*** (0.01)	0.10*** (0.01)	0.10*** (0.01)	0.09*** (0.01)	0.10*** (0.01)	0.09*** (0.01)
Incumbent inventors	0.23** (0.10)	0.33*** (0.10)	0.46*** (0.10)	0.40*** (0.10)	0.69*** (0.10)	0.57*** (0.11)
Departing inventors	-0.17*** (0.03)	0.07 (0.06)	-0.18*** (0.03)	-0.20*** (0.03)	-0.18*** (0.03)	-0.20*** (0.03)
After M&A	-0.13*** (0.01)	0.09*** (0.02)	-0.01 (0.02)	-0.05*** (0.02)	0.00 (0.02)	-0.03** (0.02)
Departing*After M&A		-0.33*** (0.06)				
Incumbent*After M&A		-1.92*** (0.13)	-1.89*** (0.13)	-1.92*** (0.13)	-1.90*** (0.13)	-2.04*** (0.14)
New key inventors			-0.24*** (0.04)	-0.60*** (0.06)	-0.04 (0.05)	-0.38*** (0.08)
New key*After M&A				0.70*** (0.07)		0.49*** (0.09)
Incumbent *New key					-3.68*** (0.58)	-2.81*** (0.76)
Incumbent *New key* After M&A						2.43** (1.15)
Observations	6105	6105	6105	6105	6105	6105
Year Dummies	YES	YES	YES	YES	YES	YES
Likelihood Ratio Test	2148.89	2042.39	2180.33	2158.14	2173.95	2160.53

Note: Table displays coefficients with standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The first column shows the basic specification including firms' size and the share of inventors and departing inventors as well as time dummies. In addition, a post-M&A dummy is included to test whether the patent outcome declines after the M&A. The estimated coefficients show the expected signs. We find that patent outcome is positively associated with firm size and the share of incumbent inventors. The marginal effects suggest that an increase of one in the firm size and inventor share variable leads to an increase of 13 percent ($=\exp(0.12)-1$) and 46 percent ($=\exp(0.23)-1$) of the number of patents, respectively. The marginal effect of inventors leaving the firm corresponds to a 19 percent decline of firm's patent output. If 18 percent of the inventors leave in the M&A period as is the case for our sample (see Table A1) the patent productivity decreases by 3.4 percent ($=19\% * 18\%$). Furthermore, we find that firms' inventive output

managerial skills, we consider it crucial to control for unobserved fixed effect in order to mitigate these endogeneity concerns, thus our choice of FE Poisson. Moreover, FE Poisson models provide the correct point estimates if only the conditional mean is correctly specified, while, negative binomial models require the correct specification of the likelihood, which is a much stronger assumption. For the FE Poisson model, this implies that even if the second moment (i.e. the variance), is not correctly specified, the point estimates and, thus the magnitude of the effect, would still be correct.

decreases in the post-M&A years; after the M&A event, the productivity is 14 percent lower, which corresponds to 2.5 patents at the sample mean.

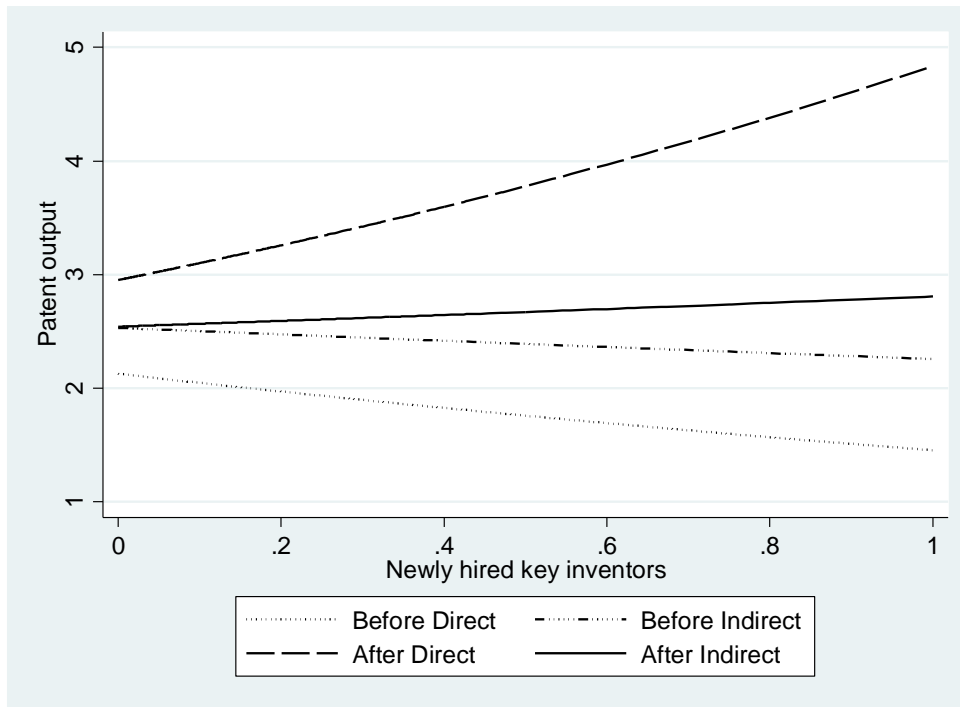
The second specification includes the variables capturing sources of invention declines at the firm level after the M&A event, namely inventor departure and productivity declines of the inventors that stay. First, we find a significant and negative effect of the interaction term between the inventor share and the post-M&A dummy, indicating that patent productivity of inventors declines after the M&A. Second, we find a negative and significant association for inventors leaving the firm after the M&A. We also find that the productivity decline of the inventors that remain in the acquiring firm is larger than the patents lost due to inventor departure. A t-test for the equality of both coefficients shows that the difference is significantly different from zero (Chi2=139.07; p-value=0.000).

The third and fourth specifications include the share of new key inventors before and after the M&A. The results show that while hiring a key inventor in the immediate pre-M&A years is counterproductive we find that newly hired key inventors are significantly and positively associated with the post-M&A patent outcome. The direct positive impact of newly hired key inventors on firms' post-M&A patenting output corresponds to an increase of 0.96 percentage points ($=\exp(-0.05+0.7)-\exp(-0.05)$)⁵. This finding is in line with hypothesis 1.

The last two specifications present the test of hypothesis 2. In support of the hypothesis, we find that there is a positive and significant indirect association between newly hired key inventors on the patenting output of incumbent inventors. The impact of newly hired key inventors on firms' patenting output through the positive effects on incumbent inventors accounts for 1.34 percentage points ($=\exp(-2.04+2.43)-\exp(-2.04)$). Moreover, the positive effect of the newly hired key inventors, represented by the triple interaction term (*INVENTORS*NEW KEY *after M&A*), outweighs the negative effect of the M&A on the inventors' productivity (*INVENTORS*after M&A*) as the test on the equality of the coefficients suggests (Chi2=13.32; p-value=0.000). The comparison of before/after and direct/indirect effects are displayed in Figure 1. Appendix II presents further analysis based on the technological intensity of firms' industries and some robustness checks.

⁵ See Shang et al. (2015) for a discussion of the interpretation of interaction effects in Poisson models.

Figure 1. Effect of newly hired key inventors on patent output



5. DISCUSSION

Although M&As are acknowledged as an important means to access innovative assets and know-how, inventive output often declines in the post-M&A period (Comanor and Scherer, 2013; Hitt et al., 1990, 1996; Ornaghi, 2009; Valentini, 2012; Veugelers, 2006). We argue and show that a measure that firms can take to enhance incumbent inventors' output after an M&A is the hiring of key inventors (Almeida and Kogut, 1999; Ganco, 2013; Groysberg and Lee, 2009; Rosenkopf and Almeida, 2003; Singh and Agrawal, 2011). The hiring of new key inventors in the post-M&A period is associated with lower levels of post-M&A inventive output declines. The hiring of key inventors affects inventive output in two ways. On the one hand, there is a direct effect in the sense that these newly hired key inventors increase inventive output after an M&A by increasing the knowledge base of the acquiring firm and, hence, accelerating the firm's invention output. The newly hired key inventors provide the acquiring firm with new skills, competencies, and experiences (Rao and Drazin, 2002), gathered at their former employer (Barney, 1991; Groysberg et al., 2008). On the other hand, newly hired key inventors improve the productivity of the inventors already working for the acquiring firm. This implies that newly hired key inventors do not only add to a firms' existing knowledge base (Rao and Drazin, 2002) but that they also

improve the exploitation of the existing knowledge base (Hackman, 2002). Hiring new key inventors sends a positive signal to incumbent inventors, reassuring that invention is of importance to the firm, even in times of corporate restructuring. As inventors have a strong preference to work with higher qualified colleagues (Barabasi et al., 2002; Wagner and Leydesdorff, 2005), newly hired key inventors can also increase the motivation and productivity of incumbent inventors (Allison and Long, 1990). In addition, newly hired key inventors can leverage their central position in the firm and their resource access to facilitate the invention process within the firm. Overall, this suggests that an appropriate hiring policy for external key inventors can counteract invention declines in the aftermath of an M&A.

Managerial Implications

While descriptive, our results suggest firms do not need to be passive observers of the consequences of M&As, but rather can take specific steps to minimize the negative effects of M&As on innovation performance. Our findings indicate managers should be proactive in setting a post-M&A human resource strategy and should focus their attention rather on the inventors that stay with the firm than on the inventors that are departing (Hussinger, 2012). This can be seen as good news for managers because it is relatively easier to foster and support the innovation activities of inventors that stay than to design attractive contracts for those inventors that are planning to leave the firm. In particular, our results further suggest that during the turbulent times that M&As represent managers should aim at recruiting top-performing inventors that have the potential to bring superior knowledge and research capabilities, and to provide new leadership in the new M&A organization.

Our results seem to be supported by previous studies and anecdotal evidence. Dixon and Nelson (2005) report that human resource professionals are often not involved in the M&A planning and execution team which is typically almost entirely comprised of people from finance, IT, and other disciplines seen as essential to making the deal work. As shown by the acquisition of Gillette by P&G, an integration team that monitors and manages the M&A process can prevent declining benefits from an M&A. To avoid brain drain and to ensure continued pre-M&A levels of invention, P&G conducted a successful key-inventors' hiring policy. Following this strategy, P&G-Gillette is regarded as one of the most successful M&As in the recent past (Kanter, 2009).

Limitations and further research

As any, our study is not free of limitations. First, the analysis presented in this paper has to be considered as descriptive. The results have to be interpreted as associations rather than as causal effects. The reason is that the effects that we analyze occur in an endogenous system of strategic choices. Firms selectively decide to engage in M&As and they do so for various reasons. Around the M&A event, major organizational and strategic decisions are taken, sometimes while managerial attention being absorbed by the M&A event itself. We addressed the endogeneity concerns of leaving and newly hired inventors to some extent by using lagged variables as regressors. A further limitation that our study shares with the majority of inventor mobility studies (Ge et al., 2016; Hoisl, 2007; Li et al., 2014; Trajtenberg et al., 2006) is that we can only define mobility based on patent documents. So, we miss the mobility of inventors that change their job without patent documentation. Furthermore, we cannot distinguish inventors who change their job from those that retire.

Following recent studies (Kaiser et al., 2018; Cassiman et al., 2018), future research could expand the research presented in this paper by including the impact of incoming inventors from universities, and compare it with that of inventors coming from other firms. Another topic of relevance for inventor mobility is non-compete agreements⁶ (e.g. Marx et al., 2009; Arts and Fleming, 2018). An interesting venue for research would be to further investigate these two areas.

6. CONCLUSIONS

Our study contributes to the literature that illustrates the importance of the transferability of knowledge across and within firms through individual talents (Kim, 1997; Song et al., 2003; Zander and Kogut, 1995) and to the literature on the role of key inventors for knowledge exploitation. We add to the prior literature by showing that key inventors play an essential role in knowledge transfer also for firms in periods of reorganization and that, as such, they can mitigate negative inventive output effects in post-M&A periods.

Interestingly, our understanding of the crucial role of newly hired key inventors, who are both directly and indirectly associated with the post-M&A inventive output of firms, echoes the

⁶ Our results hold if the subsample of countries with non-compete agreements serves as the base for the analysis. These estimations are available upon request.

classical statement by Joseph Schumpeter who mentioned that "... inventions are always associated with the rise to leadership of New Men ..." (and women, we would like to add) (Schumpeter, 1982(1939), p. 96). These newly hired key inventors act as Schumpeterian agents of change who not only alter existing routines and introduce and generate new knowledge that impacts the inventive output of the firms, through their key position within the firm, but they can also use their leadership position to disseminate knowledge to others, to motivate colleagues, and to create an innovative environment within the firm.

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APPENDIX I

Table A1. Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max	Obs.
Patents per year	17.58	87.13	0	1612	6105
Size	6.78	2.13	0	14.45	6105
Incumbent inventors	0.04	0.09	0	0.69	6105
Departing inventors	0.18	0.23	0	1	6105
New key inventors	0.06	0.18	0	1	6105

Table A2. Bivariate correlations

Variable	(1)	(2)	(3)	(4)	(5)
Patents per year	1				
Size	0.25*	1			
Incumbent inventors	0.06*	-0.29*	1		
Departing inventors	0.09*	0.09*	0.20*	1	
After M&A	0.00	0.22*	-0.15*	0.08*	1
New key inventors	-0.01	-0.04*	0.16*	0.18*	-0.07*

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

APPENDIX II

Further analysis and robustness checks

As a further analysis, we re-estimated the different specifications distinguishing industries according to the level of technology intensity. We followed the OECD (2011) classification and distinguish between low-tech and high-tech industries. In contrast to the main results and the results for the high tech sector, we do not find evidence for a direct effect of new key inventors for post-M&A inventive output in low tech sectors. This finding which is in line with Groysberg et al. (2008), who analyze security analysts, might be explained by the lack of infrastructure, complementary work practices (Ichniowski et al., 1997; Peteraf, 1993) and qualified co-workers (Groysberg et al., 2008; Hackman, 2002) for incoming key inventors that would allow them to exploit their knowledge immediately after arrival.

Table A3. High-Tech Sectors: FE Poisson regression for firms' patenting output

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.19*** (0.01)	0.21*** (0.01)	0.18*** (0.01)	0.17*** (0.01)	0.17*** (0.01)	0.16*** (0.01)
Incumbent inventors	0.32** (0.13)	0.63*** (0.14)	0.38*** (0.13)	0.33** (0.13)	1.11*** (0.14)	0.95*** (0.15)
Departing inventors	-0.11** (0.04)	-0.68*** (0.10)	-0.12*** (0.05)	-0.16*** (0.05)	-0.12*** (0.05)	-0.15*** (0.05)
After M&A	-0.03* (0.02)	-0.17*** (0.03)	0.01 (0.02)	-0.06*** (0.02)	0.02 (0.02)	-0.03 (0.02)
Departing*After M&A		0.69*** (0.10)				
Incumbent*After M&A		-0.55*** (0.15)	-0.62*** (0.15)	-0.54*** (0.15)	-0.64*** (0.15)	-0.76*** (0.17)
New key inventors			0.03 (0.05)	-0.88*** (0.06)	0.38*** (0.06)	-0.27** (0.12)
New key*After M&A				1.28*** (0.11)		0.79*** (0.13)
Incumbent *New key					-12.8*** (1.19)	-11.8*** (1.60)
Incumbent *New key* After M&A						5.76*** (2.11)
Observations	2670	2670	2670	2670	2670	2670
Year Dummies	YES	YES	YES	YES	YES	YES
Likelihood Ratio Test	1735.02	1722.28	1728.30	1712.87	1733.08	1719.78

Note: Table displays coefficients with standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4. Low-Tech Sectors: FE Poisson regression for firms' patenting output

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.05*** (0.01)	0.01 (0.01)	0.04*** (0.01)	0.05*** (0.01)	0.04*** (0.01)	0.04*** (0.01)
Incumbent inventors	0.46*** (0.16)	0.68*** (0.16)	1.08*** (0.15)	1.11*** (0.15)	0.75*** (0.17)	0.98*** (0.17)
Departing inventors	-0.19*** (0.04)	1.00*** (0.08)	-0.23*** (0.04)	-0.23*** (0.04)	-0.25*** (0.04)	-0.26*** (0.04)
After M&A	0.01 (0.02)	0.84*** (0.04)	0.33*** (0.03)	0.38*** (0.03)	0.34*** (0.03)	0.44*** (0.03)
Departing*After M&A		-1.47*** (0.08)				
Incumbent*After M&A		-5.66*** (0.24)	-5.01*** (0.24)	-4.88*** (0.24)	-5.00*** (0.24)	-6.13*** (0.27)
New key inventors			-0.36*** (0.06)	-0.14* (0.07)	-0.66*** (0.08)	-0.20* (0.11)
New key*After M&A				-0.69*** (0.13)		-1.53*** (0.17)
Incumbent *New key					3.49*** (0.59)	0.27 (0.78)
Incumbent *New key* After M&A						16.00*** (1.64)
Observations	3435	3435	3435	3435	3435	3435
Year Dummies	YES	YES	YES	YES	YES	YES
Likelihood Ratio Test	2611.77	2605.98	2741.17	2755.99	2753.91	2793.95

Note: Table displays coefficients with standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Further, to show that the output premium is coming from newly hired key inventors vs. regular inventors, we present the different models including non-key inventors⁷ (Table A5). The results show that the hiring of new non-key inventors brings a positive and significant direct effect into the acquiring firm, however, non-key inventors fail to increase acquiring firms' invention through a positive effect in their peers (the indirect effect is not significant).

⁷ Non-key inventors are defined as those inventors that are new to the firm and that do not qualify as key inventors since their number of citations is not above the 75% if the incumbent inventors at the acquiring firm. Similar to key inventors, non-key inventors is conceptualized as the ratio of non-key inventors hired at time t over the total number of inventors at time t .

Table A5. FE Poisson regression for firms' patenting output

	(1)	(2)	(3)	(4)
Size	0.11*** (0.01)	0.11*** (0.01)	0.11*** (0.01)	0.11*** (0.01)
Incumbent inventors	0.45*** (0.10)	0.49*** (0.10)	0.28** (0.11)	0.29** (0.12)
Departing inventors	-0.18*** (0.03)	-0.19*** (0.03)	-0.18*** (0.03)	-0.19*** (0.03)
After M&A	-0.01 (0.02)	-0.04** (0.02)	-0.01 (0.02)	-0.04** (0.02)
Incumbent*After M&A	-1.87*** (0.13)	-1.91*** (0.13)	-1.91*** (0.13)	-2.05*** (0.16)
New non-key inventors	-0.02*** (0.01)	-0.07*** (0.01)	-0.02*** (0.01)	-0.09*** (0.01)
New non-key *After M&A		0.07*** (0.01)		0.07*** (0.01)
Incumbent * New non-key			0.25*** (0.08)	0.30** (0.12)
Incumbent * New non-key*After M&A				0.10 (0.15)
Observations	6,105	6,105	6,105	6,105
Year Dummies	YES	YES	YES	YES
Likelihood Ratio Test	2780	2818	2791	2840

Note: Table displays coefficients with standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Moreover, the hiring of these new non-key inventors, contrary to the hiring of new key inventors, do not outweigh the post-inventive output decline of incumbent inventors ($\text{Chi}^2=147.03$; $p\text{-value}=0.00$), which confirms the existence of output premium derived from hiring key inventors.

Finally, to address the possible concerns regarding the underestimation of standard errors by the fixed-effects Poisson estimator, we re-estimate the different specifications using zero-inflated Poisson (ZIP) models, which account for the overdispersion coming from the excess of zeros in the data⁸ (see Cameron and Trivedi, 2013; Lambert, 1992; Long, 1997). The ZIP model allows overdispersion through the splitting process that models the outcomes as zero or nonzero, and similar to the hurdle models, supplement the count density with a binary process (Cameron and Trivedi, 2013). As shown in Table A6, the results, and most importantly the significance of the coefficients of interest do not significantly change with respect to the main FE Poisson regression.

⁸ In our sample, 3,476 (out of 6,105) firm-year observations have zero patent applications (approximately 57%).

Table A6. Zero-Inflated Poisson regression for firms' patenting output

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.19*** (0.01)	0.18*** (0.01)	0.17*** (0.01)	0.15*** (0.01)	0.17*** (0.01)	0.15*** (0.01)
Incumbent inventors	0.94*** (0.11)	1.02*** (0.11)	1.10*** (0.11)	1.03*** (0.11)	1.34*** (0.11)	1.12*** (0.12)
Departing inventors	-0.08*** (0.03)	-0.03 (0.06)	-0.07** (0.03)	-0.10*** (0.03)	-0.07** (0.03)	-0.10*** (0.03)
After M&A	-0.26*** (0.01)	-0.15*** (0.02)	-0.17*** (0.02)	-0.22*** (0.02)	-0.17*** (0.02)	-0.21*** (0.02)
Departing *After M&A		-0.08 (0.06)				
Incumbent *After M&A		-1.16*** (0.13)	-1.21*** (0.13)	-1.24*** (0.13)	-1.23*** (0.13)	-1.41*** (0.15)
New key inventors			-0.46*** (0.04)	-0.97*** (0.06)	-0.28*** (0.05)	-0.81*** (0.09)
New key *After M&A				0.89*** (0.07)		0.70*** (0.10)
Incumbent *New key					-3.61*** (0.59)	-1.81** (0.74)
Incumbent *New key *After M&A						3.32*** (1.27)
Observations	6,105	6,105	6,105	6,105	6,105	6,105/
Deal Dummies	YES	YES	YES	YES	YES	YES
Time Effects	YES	YES	YES	YES	YES	YES
Model chi-square	304192	304273	304413	304557	304456	304566

Note: Table displays coefficients with standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$



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