Inventor Commingling and Innovation in Technology Startup Acquisitions [*]

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Abstract: How does inventor team commingling, which we define as integrating human capital from the target and acquiring firm for R&D collaboration, impact innovation outcomes in technology acquisitions? Organizing post-acquisition R&D production teams in this manner holds the potential of sidestepping the classical integration-autonomy tradeoff. Structural integration facilitates task coordination but may dampen individual motivation, while an autonomous post-acquisition organization presents the opposite tradeoff. We argue that commingling is especially suited to technology acquisition integration and innovation facilitating know-how recombination. We assemble a sample of technology acquisitions, with some firms also experiencing prior R&D alliances with the acquirer. While structural integration reduces post-merger innovation outcomes, inventor commingling has a significant positive effect, increasing post-merger innovation outcomes for firms with more intensive inventor commingling. These effects are distinct from team knowledge diversity. Interestingly, commingling works better for firms that are less structurally integrated. We instrument direct flights between the acquisition party locations to address the issue of endogenous commingling, and find consistent results. This supports a causal interpretation of commingling on innovation. Finally, as initial evidence that innovation effectiveness of the commingling design may also depend on managerial authority and control, we find that the same inventors who engaged in pre-acquisition R&D collaboration through an alliance and post-acquisition commingling via a subsequent merger experienced greater innovation outcomes under the merged structure. These findings suggest ways to augment the knowledge-based theories of the firm as it relates to organizational design in the acquisition context.

Keywords: technology acquisitions; inventor commingling; innovation; patents; structural integration.

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1. Introduction

With the tremendous rise of venture capital investing in new ventures over the past decades, and especially in the recent past, the organizational locus of innovation is increasingly in entrepreneurial firms (National Venture Capital Association, 2021). This trend, together with the decades-old slowdown in basic investments in research among established incumbent firms (Arora, et al. 2018) has led established firms to become increasingly reliant on acquiring innovative emerging enterprises to develop new lines of business or to advance established ones (e.g., Puranam, et al., 2006). In fact, the acquisition market is one of the most significant channels by which startups achieved liquidity in the U.S. (Aggarwal & Hsu, 2014), and is likewise an important way for established firms to avoid being "disrupted" if incumbents can access the startups and technology which would have competed against them (Marx, et al. 2014).

The latter pattern is linked to the fact that acquisitions reflect a transfer of assets ranging from products to know-how embodied in individual contributors. Such know-how is increasingly recognized as valuable startup assets.[1] Successfully integrating know-how is therefore a critical component of acquisition performance, particularly in research and development (R&D) contexts. At the theoretical level, the interplay of individual and organizational knowledge lends itself to better understanding a central issue within the knowledge-based theory of the firm, which conceptualizes the firm as aggregators, orchestrators, and repositories of knowledge. Organizational knowledge can be stored in organizational routines, and are argued to be separate from individual know-how in this literature. There seems to be differing views as to the relative importance of organizational versus individual-level know-how in the literature (Kogut & Zander, 1992; Grant, 1996), however, which has been difficult to adjudicate from theory alone.[2] For

[1] The rising phenomenon of "acqui-hiring" (e.g., Chatterji & Patro, 2014) reflects this recognition of know-how embodied in individuals. At the same time, we know from the literature that entrepreneurial exit events also tend to loosen the bonds of individuals to their employers (e.g., Stuart & Sorenson, 2003). However, a key missing perspective in this literature is organizing human capital in the context of M&As, particularly in technology acquisition contexts in which human capital and intangible assets are thought to be core assets motivating the acquisition. Puranam et al. (2003) quote a Cisco manager in the context of acquisition: "Usually we purchase a specific piece of technology or a product. But that is only half the story, we also want the team which will generate innovation in the future."

[2] Kogut & Zander (1992) discuss the many differing levels of analysis associated with organizational knowledge, which may be partly why there has been sparse empirical work in this domain (given the challenges of measurement).

example, Kogut & Zander (1992) reason that organizational competence is not overturned when individuals leave the firm, and so conclude that organizational routines and processes must be the ones which are rare and inimitable. Our empirical context allows us to hold the knowledge level and diversity of individuals (with a R&D production team) constant, while examining a proxy for recombining knowledge of organizational routines and procedures which "live" in individuals. While the prior literature has tended to silo knowledge at the individual level as juxtaposed against that resident at the organizational level, the work here suggests that there are more subtle elements of organizational memory, routines and knowledge which are reflected in workers, with important implications when they move across different organizational contexts (as in an acquisition).

Whether the primary impetus for acquisitions is based on know-how or products, a long-standing literature suggests disappointing post-acquisition innovation outcomes (e.g., Hitt, et al. 1990; Kapoor & Lim, 2007; Cloodt, et al., 2006). We concentrate in this paper on post-merger integration as compared to pre-merger selection (which we treat as exogenous to our analysis). A leading discussion in the literature on post-acquisition integration poses a tradeoff between autonomy pitted against integration (Ranft & Lord, 2002). While organizational structural integration (defined in this literature as combining formerly distinct organizational units into the same organizational unit in the post-acquisition period) has been argued to sometimes be necessary to achieve coordination and leverage acquired knowledge of the acquired entity (e.g., Puranam & Srikanth, 2007; Puranam, et al., 2009), it brings considerable disruption to the target companies (Haspeslagh & Jemison, 1991; Paruchuri, et al., 2006). This illustrates the long-standing recognition of the autonomy-integration tradeoff to which we propose a potential means of achieving a middle-ground in organizing technology acquisitions.

We argue that organization design for innovation within the context of acquisitions has paid insufficient attention to unsticking individual-level knowledge, particularly the part related to higher-level organizational knowledge. While organizing for coordination is certainly important, we argue that a more subtle analysis of team collaboration across firm boundaries (in the context of acquisitions) is perhaps just as important. The consequence is a new form of organizing production teams, which we term team *commingling*. We define it as integrating inventive human capital from the target and the acquiring firm. We propose this structure as an effective alternative means of leveraging acquired technology capability outside of the typical dichotomous choice of structurally integrating formerly distinct organizational units or leaving the acquired entities as near-autonomous units. Unlike organizational structural integration, team commingling involves individual-level integration, which may be less disruptive, yet also facilitates innovation in target firms. Starting from individual-level origins, we conceptualize and align our empirical measurement of inventor commingling to address a multi-level conceptualization and dynamic treatment of this organizational investment in human capital integration.

We pose the following research question: what are the innovation implications of inventor commingling on the innovation output of the acquired firm? This is a specific form of the more general research domain we address, namely: how should managers organize R&D production teams for innovation in the context of acquiring technology startups? Framed in this way, and using the lens of the knowledge-based view of the firm, we aim to contribute to that literature by empirically examining how the pre-existing dichotomous choice of integrate versus leave autonomous can be expanded to one which embraces a third way, one which is rooted in human resources at the team level. In so doing, we explore the intersection of organizational design and knowledge objectives which move beyond the traditional call for structures which address coordination challenges. While those challenges are salient, we argue that a potentially overlooked factor in organizational design is the imperative to unstick knowledge from individuals and to organize for cross-firm team collaboration alongside organizing for task coordination.

Our empirical analysis uses a broad-based sample of technology venture acquisitions (not conditioned on receiving venture capital), which also contains approximately 30% non-US acquisitions. We find that the degree of post-acquisition firm-level inventor commingling is positively related to innovation output (as measured by granted patents and forward citation weighted patents) and exploration (patents with new-to-the-firm technology classes), especially in the absence of post-acquisition structural integration. These relationships hold after accounting for inventor team technical experience diversity, which the literature has identified as an important contributor to innovation. We address the issue that unobserved and unmeasured managerial choices likely shape the degree of inventor commingling. To do so, we investigate whether our results hold once we adjust the estimates by exploiting the exogenous introduction of direct flights between acquirer and acquired entity locations. Such flights exogenously shift the cost of commingling, allowing us to construct an instrumental variable for commingling (note that the acquisition event itself is still exogenous to our analysis, as we aim to contribute to the post-acquisition integration rather than the acquisition selection literature). Our original results hold, providing support for a causal relationship from commingling to innovation outcomes.

A final analysis exploits the fact that inter-organizational R&D collaboration occurs in our sample prior to some acquisitions. This allows us to examine innovation outcomes of *the same* inventors under an inter-organizational cooperation pre-acquisition structure as compared to a commingled post-merger team structure. We find that inventor level innovation outcomes are higher when commingling under the post-acquisition structure (after accounting for a host of inventor controls and a variety of fixed effects), which has implications for areas to augment the knowledge-based theory of the firm.

This work advances the literature in two main ways. First, while most post-acquisition integration studies discuss top-down organizational design with considerable emphasis on structural integration, we study an alternative structure through which knowledge embedded in individual and organizational contexts can be unstuck and recombined for innovation via commingling. This follows the knowledge-based view tradition (e.g., von Hippel, 1994; Grant, 1996). Second, the effectiveness of inventor commingling may depend on the organization of collaboration (alliance compared to post-acquisition structures) as well as on the degree of structural integration between post-merger entities, and so studying inventors under these alternatives represents a window into how the form of collaboration may impact innovative outcomes. Both themes have received scant attention in the post-acquisition integration literature. We end with a discussion of implications, limitations, and future research directions.

2. Literature and Hypotheses

2.1 Background: Organizing Post-Acquisition Operations for Innovation

Accessing knowledge outside of an organization's boundaries can be instrumental to its competitiveness (e.g., Cohen & Levinthal, 1990), especially when the requisite knowledge for innovation is not entirely resident in the focal firm. As Rosenkopf & Almeida (2003: 762) succinctly note: inter-firm knowledge transfer can effectively fill in holes in [the focal firm's] knowledge landscapes." Technology acquisition is frequently taken as an effective vehicle to expand firms' knowledge landscapes (e.g., Kale & Puranam, 2004; Puranam & Srikanth, 2007), though the organization of the merged entity has largely been dominated by discussion of the integrated form in the recent literature, with the presumption that coordination is the central challenge which should dictate the organizational form (so organizational form follows the coordination function). More generally, in assessing whether to engage in acquisition efforts, firms might be unwilling to pay for *effort*, as one would have to do in managing R&D efforts, and instead pay (presumably a higher rate) for successful innovation *outcomes* (e.g., products or technological solutions).

Having decided to pursue the acquisition path to access external knowledge, the post-acquisition integration literature has identified a key managerial decision to be the choice of whether organizational units should be owned but autonomously separate from the parent organization. There is little analysis within the acquisition literature, which seems to be focused on an individual incentive motivation. The argument is that individual innovation incentives are strengthened under autonomous operations post acquisition since inventors and managers output will not be obscured by integration attempts with the acquirer, resulting in higher-powered incentives (Kapoor & Lim, 2007). It is important to keep in mind the broader challenge of incentives for innovation: because failure is a common outcome in innovation, and failure can stem from total lack of effort as well as from full effort, it is often thought that monitoring is important in structuring the post-acquisition unit.

Relatedly, while not drawn from the acquisition literature, Christensen (2013) highlights a potential solution to the "innovator's dilemma" of disruptive innovation, in which customer value is initially low, but has a steep rate of improvement in ways which are difficult for incumbents to recognize and react. Christensen suggests developing the potentially disruptive innovation in an autonomous unit separate from the rest of the incumbent organization as a means of insulating the unit from managerial pressure. This illustrates the sequestration potential of autonomous operation. Of course, the drawback on complete autonomy (structural separation) is the absence of know-how spillovers, whether the context is acquisition or business units within an organization.

At the other end of the spectrum, structural integration has the chief benefit of coordination in the face of interdependence (e.g., Puranam, et al. 2006), especially when mutual adjustment of firms' activities is necessary (e.g., in traditional vaccine development, the manufacturing process is mutually dependent on experiments determining the level of weakened virus necessary to elicit an immune response, etc.).[3] The tightness of coordination depends on the task environment itself (Thompson, 1967). Managerial hierarchy and formal control and authority are also key themes which enable coordination in this literature. However, as Raveendran et al. (2020) point out, many of the theories of organizational design were born in the 1950s and 1960s, a time period in which innovation was primarily taking place in large, multidivisional corporations.[4] The locus of innovation has dramatically shifted away from such organizations steadily over the intervening decades (Arora, et al. 2018). Instead, universities and startups are increasingly important engines of innovation, due in part to private equity investments as well as markets for technology transfer (Hsu, et al. 2007).

Coordination is still important, but alternate organizational forms outside of structural integration may be suited to attain sufficient coordination while at the same time preserving sufficient autonomy to induce innovation. To explore this, we examine individual and team level dynamics, in line with the move to better understanding "micro-foundations" of organization-level phenomenon.

[3] Some authors have suggested that initial autonomy followed by integration may be a way to escape the autonomy-integration dilemma (e.g., Haspeslagh & Jemison, 1991; Ranft & Lord, 2002), but as Graebner (2004) notes, this solution may not be ideal in the technology context given the typically dynamic environments.

[4] Even the classic contribution of Nelson & Winter (1982: 97) is explicit about the organizational circumstance of their evolutionary theory: "…the framework applies most naturally to organizations that are engaged in the provision of goods and services that are visibly 'the same' over extended periods—manufacturing hand tools, teaching second graders, and so forth—and for which well-defined routines structure a large part of organizational functioning at any particular time."

2.2 Inventor Commingling and Innovation

Inventors in commingled teams are from originally separate organizational entities (before an acquisition) and hold distinct tacit knowledge about managing innovation (via knowhow, policies, procedures and norms). By forming a commingled team and collaborating on specific projects, tacit knowledge from the two entities can be unstuck and recombined through interaction and integration (Hoisl, et al., 2017). Team commingling provides an opportunity to recombine individuals' technical knowledge domains within the context of diverse higher-order organizational knowledge routines; we therefore expect commingling will have an independent effect separate from team knowledge diversity. We recognize that commingling may interact with structural integration, but note that the constructs are distinct in that firms can employ one practice without necessarily engaging in the other (as the former takes place at the team level of analysis, while the latter takes place at the organization level).

The recent post-acquisition integration literature examines the efficacy of organizational design, such as structural integration (Puranam, et al., 2006; Puranam, et al., 2009). Structural integration has been found to be organizationally disruptive however, as Puranam et al. (2009: 313) note: "acquirers who buy small technology-based firms for their technological capabilities often discover that post-merger integration can destroy the very innovative capabilities that made the acquired organization attractive in the first place." This can occur due to individual-level disruptions upon acquisition, especially in knowledge-oriented contexts (Ernst & Vitt, 2000). The operative mechanisms behind individual inventor disruption may stem from the loss of social status on the part of inventors in the acquired firm (Paruchuri, et al., 2006) as well as induced information asymmetries (Kapoor & Lim, 2007).

Unlike structural integration, team commingling does not require dramatic organizational structural change but instead can involve a progressive, human capital integration process. It therefore brings fewer disruptions to the acquired inventive teams than structural integration does because the acquired entities can maintain autonomy while the R&D teams of the two entities commingle with each other. The incentive structure to motivate innovation and the social status of acquired inventors can remain aligned and preserved in the commingling process, which can promote innovation.

At the same time, team commingling as an informal integration vehicle may preserve some of the benefits of structural integration by forming common ground (shared knowledge) through collaboration. Puranam et al. (2009) investigate the necessary conditions for structural integration. The authors point out how structural integration enables coordination between acquiring and acquired organizations. Coordination is the alignment of actions, which means interacting individuals and firms can adequately anticipate each other's actions and adjust their own accordingly (e.g., Grant 1996; Puranam et al. 2009). If coordination and alignment between the target and the acquirer exists, the need for structural integration may decline because people who possess similar stocks of knowledge can also coordinate without formal arrangement, and vice-versa. By collaborating on joint projects, shared knowledge is created. For example, blueprints, documentation, or artifacts may be developed in the commingling process, serving as a guide for current and future interdependent R&D activities. Therefore, team commingling may be a preferred alternative to structural integration, providing many of the benefits of structural integration while incurring lower inventor and organizational level interference which may reduce post acquisition innovation outcomes. We propose:

- **H1a**: *Firm inventor commingling is a preferred alternative to formal structural integration for innovation outcomes.*
- **H1b**: *Post-acquisition inventor commingling positively affects innovation outcomes more when structural integration is low.*

To delve deeper in how the post-acquisition organization of human capital can influence innovation outcomes, we characterize and build on several themes in the existing literature. One part of the literature has tended to focus on individual knowledge (e.g., von Hippel, 1994) as well as team knowledge (Aggarwal, et al. 2020; Hoisl, et al. 2017), with the basic finding in the latter case that diverse knowledge is associated with better innovation outcomes. Prior research has documented inventor team knowledge diversity's positive relation to innovation outcomes (e.g., Hoisl et al., 2017). However, following Aggarwal et al. (2020), we suggest that even with a given set of individuals with an associated span and diversity of (technical) experience, the way invention production teams are organized is a significant organizational design choice, with likely innovation consequences. This is because such design impacts organizational (not just individual) knowledge recombination. "Knowledge" in this context refers to both technical knowledge and routines at the individual level as well as know-how at the organizational level. As the knowledge-based view has highlighted (Kogut & Zander, 1992; Grant, 1996), firm-level knowledge is more than the simple addition of their individuals' knowledge. Organizational know-how is tacit but essential for knowledge transfer (Teece, 1977). Because both the task and solution environments are typically ill-defined in R&D, tacit knowledge is particularly important in innovation. Therefore, unsticking tacit knowledge is an essential first step to initiating innovation (von Hippel, 1994; Szulanski, 1996). Furthermore, the most effective means of accomplishing this is through an iterative process of co-locating individuals with the requisite information with others who may have the appropriate problem-solving skills (von Hippel, 1994) – which is the structure we study under inventor team commingling.[5]

In a separate literature, scholars concerned with organizational design have overwhelmingly focused on organizing for coordination in the face of task interdependencies. While we acknowledge that coordination challenges are certainly important, we argue that an overlooked driver of organizational structure in the literature is task *uncertainty*, which is characterized as a context in which work in the unit is both difficult and variable (Van de Ven, et al. 1976), as would be the case in R&D driven contexts. To address such challenges, a horizontal "group" mode (Lawrence & Lorsch, 1967; Galbraith, 1973; Van de Ven et al., 1976) may be considered. In such an operational mode for developing plans, a group of role occupants through scheduled and unscheduled meetings are charged with making mutual adjustments. Unlike the traditional "personal" mode (Thompson, 1967), which is hierarchical (e.g., unit supervisors), the group mode has no formal authority over individuals (just a designated coordinator). Therefore, a group mode may assist in both task uncertainty and task interdependence (to address coordination challenges), and because it is non-hierarchical, it may be particularly useful in some contexts. For example, Hutchins (1991) traces the switch from routine- to group-problem solving during a crisis.

[5] To put the spotlight squarely on differences in organizational routines, we empirically hold constant a host of individual-level differences such as proxies for inventor quality and technical breadth, as well as team/group level differences such as knowledge diversity.

While the past innovation literature has focused on innovation resulting from recombination of *technical* knowledge (Fleming, 2001), we focus on recombination of *organizational* knowledge, as embedded in individuals, as a vehicle for organizing innovation (in line with the knowledge-based view). This is a conceptual break from the literature, in that individuals and organizations have classically been theorized to each hold their own forms of knowledge (Kogut & Zander, 1992). Interestingly, there is a tradition in the evolutionary theory of the firm of tracing the notion of organizational "routines" to individual skills. Indeed, as Nelson & Winter (1982: 115) note: "The loss of an employee with such important idiosyncratic knowledge poses a major threat to the continuity of routine—indeed, if the departure is unanticipated, continuity is necessarily broken." The expanded notion of individual knowledge beyond "information" and technical "know-how" to encompass embedded memory of organizational routines not only accords with the spirit of the entrepreneurial spinoff literature in which founders bring new knowledge and their experience to the new venture, but also helps reconcile theoretical tension as to the proper unit of analysis at which to conduct an empirical analysis of the knowledge-based view. We propose that commingling inventors not only unsticks and recombines technical knowledge useful for innovation, but it also fosters new organizational routines for innovation by recombining those from individuals' past organizational experiences.

Recombining knowledge at the organizational level is also facilitated by inventor team commingling. In the language of Nelson & Winter's (1982) evolutionary theory, this causes organizational routines to mutate. As to whether the mutation is beneficial or counterproductive, because the acquisition is directed (as compared to a "random" mutation), Nelson & Winter (1982: 116) suggest that the mutation might be beneficial: "…it is highly unlikely that undirected change in a single part will have beneficial effects on the system. This, of course, is the basis for the biological proposition that mutations tend to be deleterious on the average." Another difference between the genetic analogy of biological mutation is the agency associated with individuals on a team in (selective) adaptation of new organizational processes. Through direct comparison and evaluation of, in some cases, alternative processes of approaching a given uncertain task, R&D production teams can engage in a perspective hybridization, with the benefit of a more diverse set of approaches than would be the case as compared to production teams staffed with more homogenous organizational backgrounds.[6] To highlight the distinct benefits of commingling in an acquisition context we state the following hypothesis:

- **H2**: *Acquired firms which commingle their inventors more intensively are causally related to more favorable innovation outcomes, holding constant team knowledge diversity.*

2.3 Organizational Form of Commingling

If aggregating and integrating both organizational and individual-level knowledge are core building blocks of the knowledge-based view of the firm, then it follows that such activity will have implications for the boundaries and scope of the firm (Kogut & Zander, 1992; Grant, 1996). In particular, organizational boundaries will be shaped by the relative costs and benefits of alternative ways of organizing the knowledge function (ranging from complete ownership as is the case under acquisition, to less integrated alternatives such as via the market or alliances).

In our empirical context, inventor collaboration can occur under two organizational forms: pre-acquisition R&D alliance versus post-acquisition commingling where inventors from the acquired and acquiring firm jointly perform innovation tasks. Given that prior alliances between counterparties are common in technology acquisition (Zaheer, et al., 2010), individual-level cooperation in alliance arrangements may not be rare.

Under the knowledge-based theory of the firm, the arguments in the prior section of the benefits of commingling to unstick individual and organizational knowledge might also accrue to the alliance form of pre-acquisition individual-level cooperation. That is, individuals involved in joint (inter-organization) invention teams possess organizational knowledge about the routines available for recombination. If unsticking and recombining such know-how were sufficient for innovation, then we would expect that the

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[6] The process described here is reminiscent of observations made in the venture spinoff literature. To the idea of processes and procedures moving across organizational contexts via founder behavior, consider this quote from the founder of the MIT spinoff, Digital Equipment, Olsen (1983: 11): "We also brought some organizational ideas from MIT [to DEC]...We had so much confidence in MIT that we even followed the MIT operations manual. We took the same hours, we took the same vacations, we paid the same holidays."

more targeted alliance form would yield the same amount of innovation, yet be achievable at lower cost to the organizations. This is because there are significant costs associated with acquisition, which are avoided under an alliance form. To take one significant example, consider the reversibility of an alliance as compared to an acquisition. Dissolving an alliance is much less costly as compared to an acquisition (which is related to the common feature of "break-up" fees associated with acquisitions which do not close).

One major difference, however, between the two forms of R&D collaboration is ownership and control. Under an alliance, the parties are separate entities with their own control over strategic resources on a firm-wide basis. Therefore, the counterparties must contractually specify the boundaries of the joint development (Ryall & Sampson, 2009). Since the task environment is ill-defined in the R&D context, it is not unusual for alliance contracts to contain unverifiable and unenforceable covenants (such as number of man-hours required, but with no mechanisms to monitor or verify this). These unverifiable covenants increase the governance and oversight costs of managing teams with representation from each organizational entity, and may diminish knowledge-transfer and recombination efficacy (Robinson & Stuart, 2007). Additionally, since alliance-based collaboration is typically at the *project* level, such teams may compete with internal teams for resources. As a result, the lack of common ownership may lead to resource misappropriation. Without proper support and the necessary resources under the alliance structure, inter-organizational collaborative R&D teams may bring only limited enhancement to innovation productivity.

Acquisitions reduce these governance issues. Common ownership enables flexible decision-making in directing the commingled team (without the need for ex-ante contracting, which would be the case under an alliance), a particularly important benefit in R&D contexts which are marked by solution environment uncertainty. When the parent company has the legal ownership of the target firm, issues of misaligned incentives and uncertainty in control no longer exist (Ranft & Lord, 2002). Control and authority of technical human capital therefore enables the overriding benefits for realizing synergies through closer knowledge sharing (Dyer, et al., 2004). Because of the fluid nature of R&D, it may be difficult or at least very costly to contract on (in an alliance arrangement) all the ex-ante elements which might be important in shaping innovation outcomes. By contrast, under common ownership (the acquisition form), managerial fiat prevails over the need to contract at the project-level. In summary, if unsticking and recombining individual and organizational knowledge is sufficient for innovation, we might expect the first of the below predictions to hold (given the costs associated with acquisition as compared to alliance forms). However, if control and governance considerations associated with an acquisition are *also necessary* to achieve innovation benefits, we would expect the second prediction to instead hold:

- **H3a**: *The same inventors will be **less** innovative when commingling post-acquisition as compared to under a pre-acquisition R&D alliance*.
- **H3b**: *The same inventors will be **more** innovative when commingling post-acquisition as compared to under a pre-acquisition R&D alliance*.

3. Data, Variables and Empirical Strategy

To test these predictions about innovation and inventor commingling, we first describe our data construction. We then discuss our main variables, which are at both the firm-year and inventor-year levels of analysis. The section ends with a short discussion of our empirical strategy.

3.1 Data Construction

We start with the set of firms listed in Crunchbase, a platform concentrating on emerging ventures, which were listed as acquired between the years 1970 and 2014 (since our measure of innovation quality is based on forward patent citations in the 4 years post-grant, we stop the analysis window before the data end in 2018). This yields a list of 44,834 acquired companies. Since a Crunchbase listing is not dependent on receiving venture capital funding, nor conditional on being US-based, we believe that this database allows us to cover a broad sample of startup firm acquisitions.[7]

[7] We compare the Crunchbase data to two datasets to assess coverage quality. First, we examine the overlap between Crunchbase listings of ventures acquired from Israel to an Israeli data source of venture capital-backed startups in Israel, known as the IVC Research Center database. Since Israel is well-represented in technology acquisitions of technology-centric startups, we believe that this comparison is worthwhile. We find that the Crunchbase data is quite comprehensive in its coverage (by comparison, established venture capital data sources such as Thomson One do not systematically cover international transactions). Second, we compare Crunchbase coverage of technology acquisitions to SDC Platinum, a standard dataset used for acquisition data. We find that the SDC coverage skews toward larger firms and misses many smaller firm acquisitions, which is of particular relevance to us. To further compare the quality

We then use the set of acquired firms to build a longitudinal database at both the acquired firm and inventor levels. To do so, we make use of the PatentsView dataset provided by the United States Patent & Trademark Office (UPSTO). We drop acquired firms not granted any patents between 1976-2014 as listed in PatentsView to help us focus on acquisitions that are likely driven by technology-centric motivations (while acknowledging that we might miss non-patented knowledge, such as that protected by trade secrecy). There is also a pragmatic reason in that our key empirical variables are derived from patent information, as we discuss below. We fuzzy match (using the Stata 15 built-in "reclink2" software package) acquired firm names from Crunchbase with patent firm assignees listed in PatentsView. We find an overlap of 7,404 firms in both databases. Finally, we exclude multiple acquisition situations of the same firm to ease interpretation. This leaves a final sample of 6,478 acquired firms in our analysis.[8]

We then gather a list of all the inventors whose patents were assigned to the focal acquired companies using the unique inventor identifiers contained in the PatentsView database. This allows us to build a patenting history of each inventor over her/his career, both before and after patenting in the focal firm, if applicable. These inventor- and patent-level data are crucial for measuring the key constructs, such as inventor commingling (as we explain in the next section). We assume an inventor was working for an assignee if the majority of patents she invented in a given year were issued to the assignee. An inventor is considered to have switched employers when most of her patents start to be assigned to a different company. One exception is when an acquired inventor's patents are assigned to the acquirer after the acquisition. If that is the case, we still consider the inventor as the target company's employee and take this kind of assignment as evidence of structural integration (inspired by the empirical measure advanced by Arora, et

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of these two databases, we examine the listed acquisition data in each database as compared to that contained in the IVC data for the set of Israeli acquisitions (with the assumption that the local data provider, IVC, is most likely to be a "gold standard" on data quality). We find that the Crunchbase dataset dramatically outperforms the SDC database.

[8] In the interest of space, we do not provide a "thick" description of the overall data, but consider the following facts: (1) acquisition events become much more prevalent as we approach the present; (2) the top three industries of the acquired firms are: communications (23%), health and medical-related (19%), and motor vehicle-related (7%); (3) the top four nations of the acquired firms are: US (71%), UK (6%), Germany (3.6%), and Canada (3.4%); (4) within the US, the top three states of venture location are: California (31%), Massachusetts (8.5%), and Texas (6.1%); and (5) the top three acquiring firms in our sample are: Microsoft (0.58%), IBM (0.57%), and Cisco (0.41%).

al. 2014). Of course, patent assignment records can only indicate inventors' employers in years where patent applications are observed. In the absence of other intervening assignees, we assume that an inventor continued his or her employment with the same employer during the period spanning consecutive patent applications. Integrating the inventor-employer affiliations with the acquired-firms patent records identifies 717 target firms that engaged in commingling.

3.2 Variables and Measures

3.2.1 Outcome variables. *Firm patent stock* is defined as the cumulative number of patents assigned to a given target or invented by the target's employees and assigned to its acquirer after the acquisition, with priority dates before a certain year. Similarly, *inventor patents stock* is the cumulative number of inventors' patents with the priority date before a given year. These are measures of innovation quantity commonly used in the literature. To measure innovation quality, we follow the convention in the innovation literature by weighting the patent grants by the number of forward patent citations over the following four years post patent grant (and calculating the stock), resulting in the variable, *firm forward citations stock*.[9] We aggregate this variable to the firm-year level of analysis, and examine the variable at the inventor-year level as well (*inventor forward citations stock*). Finally, to measure innovative activity broadening, we construct the variable, *firm cumulative patent classes*, which is a cumulative count of the number of main (3-digit) patent classes up to a given year (for analysis at the firm level), or at the inventor level (*inventor cumulative patent classes*). Variable definitions and summary statistics are in Table 1, while correlations are available on request (we do not detect multicollinearity concerns).

---TABLE 1 ABOUT HERE---

3.2.2 Explanatory variables. We define a *commingled* patent as one that is produced by inventors coming together from the target and the acquiring firms. To construct the measure of commingling we take the pool of patents assigned to the targets (329,504 patents) and compile a list of 64,764 inventors associated

[9] Our data analysis spans acquisition transactions through 2014 and the associated patent data up to 2018, given the time lapse between patent filing and grant, and the four-year moving window used for forward citation tracking.

with these patents. We track the assignment history of the associated inventors. A commingled patent is produced when inventors come together from the acquired and acquiring entities. Under this definition, there are 7,932 commingled patents in the patent pool. *Firm commingling intensity* is the share of the acquired entity's cumulative patent stock invented by commingled teams (*inventor commingling intensity* is similarly constructed).

To test H1a and H1b, and study the relative importance and interaction between commingling and structural integration as they relate to innovation outcomes, we adopt the concept developed by Arora et al. (2014) in constructing a structural integration proxy by tracking the ratio of acquired entity patents assigned to the parent corporation. We define the variable *structural integration proxy* as the three-year moving average representing the portion of newly-created patents invented by the acquired entity inventors but assigned to the acquiring entity out of the total number of patents invented by acquired entity inventors during the period. By definition, we set this variable to 0 prior to the acquisition date. As Arora et al. (2014) note in their paper, this measure is imperfect, yet it is a scalable proxy for the delegation of authority or autonomy in R&D management. *Post-acquisition* is a dummy variable for years after the acquisition.

To test H3a versus H3b, comparing the effect of inventor innovation output under a pre-acquisition collaboration regime to an integrated post M&A regime, we narrow our sample to the set of 493 companies where we have evidence of pre-M&A R&D collaboration between acquired and acquiring firm inventors. We select all of the inventors employed by these firms before the acquisition who stayed with the focal acquired firm at least 5 years after the acquisition. These criteria are guided by the comparison we wish to make, which is inventor innovation in an integrated post-acquisition organization as compared to a pre-acquisition cooperative mode which is not organizationally integrated. We assemble an inventor-year data panel. *Inventor commingling intensity* is defined as the share of commingled patents in inventor *j*'s patent stock. Note that the pre-M&A R&D collaboration criteria is applied at the firm level, and so the inventor-level analysis includes inventors that did and did-not conduct collaborative R&D pre-M&A.

***3.2.3 Control variables*.** At the firm-year level, we construct a number of variables that control for various aspects of the acquired firm's patent position and inventor experience. *Firm team knowledge* *diversity* is the within-team knowledge diversity across all inventor teams which have patented for the focal firm before the focal year.[10] *Firm technology concentration* is a Herfindahl index of 3-digit (main) patent classes in the firm's patent stock up to year *t* (higher values indicate more concentration of patent classes). The variable, *firm inventors*, is a count of the number of distinct inventors at the firm in year *t*. The final three control variables in this series give firm cumulative averages of inventor innovation activity (*firm inventor avg cumulative patent counts*, *firm inventor average cumulative fcitation*, and *firm inventor avg cumulative patent classes*), somewhat akin to lagged outcome variable controls. Finally, two variables control for the acquired firm's investor base and external funding activity: *firm cumulative funding rounds* and *firm cumulative VC investors*, in each case, up to the focal year.

At the inventor-year level of analysis, aside from acquiree-inventor fixed effects, we construct a measure of *inventor-team knowledge diversity* defined as the average angular distance between the knowledge experience of the focal inventor and that of other inventors who have co-invented with her. We further control for *inventor co-located*, an indicator for whether the inventor's most recent residential address (as listed in PatentsView) is located within a 100km distance from the acquirer's R&D center (see the next section for method), as it represents an alternative means of unsticking tacit knowledge.

3.2.4 Instrumental variable. We construct R&D location innovation outcome variables akin to our three main outcome variables: *location patents stock*, *location forward citations stock*, and *location cumulative patent classes*. The endogenous variable in this set up is *R&D location commingling intensity*, which is analogous to the other commingling intensity variables, though the unit here is an R&D location. We exploit the introduction of direct flights between R&D locations and construct the instrumental variable *location connectedness* (defined as the number of acquirer's R&D locations which have direct flights to location *l* in year *t*) in the *post acquired* period. Finally, *location knowledge relatedness* is a control variable for the share of knowledge base overlap between the acquirer and location *l*, following Ahuja & Katila

[10] Within-team knowledge diversity is defined following Aggarwal, et al. (2020) and references therein, as the average of the angular distance between the knowledge experience of each pair of inventors on a team where experience is measured by patent class experience vectors.

(2001). We further construct our patent controls at the R&D location level, akin to the firm level controls discussed above but limited to the specific R&D location data (see Table 1).

We now provide details of constructing the instrumental variable. We first identify the R&D locations of the focal firms. We take advantage of inventor residential address information to examine the geographic location of their firm's R&D activities. For each focal firm we cluster these addresses at the patent level, aggregating to a circle with a radius of 50 kilometers (km). We then group these clusters based on their centers so that all circles for which the center can be placed within a circle with a radius of 50km will be considered part of the same R&D location. We define the center of each of these resulting clusters as an R&D location of the focal firm.[11] Through this process, we identify 7,499 R&D locations associated with the 717 focal acquired companies, spread across 69 countries as well as 20,231 R&D locations of 521 acquiring firms located in 114 countries. We use the Air Carrier Statistics database, also known as the T-100 data bank, from the US Bureau of Transportation Statistics to identify direct flights.[12] For the 6,519,684 dyads of acquired-acquiring R&D locations, we identify all airports within 100 km to the center of each focal R&D location (which rests on an assumption of household commuting distance to the relevant airport). We aggregate the monthly data to the annual level and classify a location dyad as connected in a given year if there is at least one direct flight operating throughout the given year between the airports serving the focal R&D locations.

3.3 Empirical specification. We want to estimate the impact of commingling on post-acquisition organizational innovation performance of target companies. Our analysis is therefore at the firm-year level of analysis. Given the count nature of our outcome variables, our main specifications are fixed effects

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[11] The median number of acquired firm R&D locations is one, however some acquired firms are large and distributed, resulting in an average of 10.4 R&D locations per acquired firm. Since some acquirers are very large, we keep the top 100 R&D locations for this group

[12] The database contains monthly reports from 1980 to 2018 for all flight routes of certified US air carriers which have at least one point of service in the US or its territories and has been used in the literature to construct direct flight instruments which address the endogenous choice of geographic location.

conditional Poisson regressions (though the results are robust to OLS estimation as well).[13] We use a one-year lag term of team commingling intensity in the regressions to account for temporal lags in production (our results are robust to longer time lags). To test the effects of structural integration we use our three-year moving average *structural integration proxy* which by construction results in a similar one period average lag to innovation production outcome variables. We include a host of controls for firm and inventor composition variables, as well as acquirer and target firm fixed effects. Since post-acquisition integration is not randomly determined, we interpret these results as correlational. Our controls also include a measure for inventor team diversity; this is intended to test whether commingling has an independent effect beyond increased team diversity. To assess the degree to which the results might be driven by selection (rather than treatment) effects, we exploit an exogenous shift of the costs of firm-level commingling. The introduction or removal of direct flights between the location of the acquiring and acquired firms is a decision outside of managerial control. In a two-stage least squares regression, we use direct flights between the location dyad, post-acquisition, to instrument for the potentially endogenous variable, *R&D location commingling intensity*.

To test H1a and H1b, we examine the coefficients of *commingling intensity* and the *structural integration proxy* as well as their interaction term. To test H2 we first estimate the positive correlation with a Poisson regression, utilizing our *commingling intensity* variable and its interaction with the *post-acquisition* indicator as well as incorporating the *team knowledge diversity* control. We then provide evidence for causality with the instrumental variables analysis using two-stage least squares estimation.

We address the potential concern of post-M&A inventor selection (i.e., inventors or inventor teams that successfully collaborated pre-M&A are potentially more valuable to the post M&A entities and would have a higher representation in the post M&A cohort). We do so by re-running the above specifications

[13] Overdispersion is a well-known issue with the Poisson model (the conditional mean in empirical data typically is smaller than the variance). To address concerns about overdispersion, we cluster and implement robust standard errors in the panel conditional Poisson model. We also re-estimate our models using a conditional fixed-effects negative binomial model instead, and we find consistent and statistically significant results to those reported where the negative binomial models converge.

limiting our data to acquired firms where R&D collaboration between acquired and acquiring entity inventors only started after the acquisition date. This analysis also allows us to verify the effect of post-M&A commingling without the potential persistence effect of pre-M&A R&D collaboration on post M&A innovation output.

To conduct our inventor-level organizational form tests (H3), we switch to the inventor-year level of analysis and confine the sample as previously mentioned. We examine the inventor-level analogs of the innovation-level outcomes, and use a similar approach, again in a Poisson regression framework given the count nature of the outcomes.

4. Results

Table 2 tests the relationship between firm-level inventor commingling and innovation outcomes. The unit of analysis is a firm-year. For each of our outcome variables, *firm patents stock*, *firm forward citations stock*, and *firm cumulative patent classes*, we present four regression results: the first three regressions use all target firms in the sample. The first specification includes just the key variables, the second incorporates the interaction variables and the third adds to the specification the set of firm-level control variables listed in Table 1. The final set omits from the sample target firms which exhibited patented collaboration with the acquiring firms prior to the acquisition.[14] Fixed effects for year, acquiree and acquirer are incorporated in all models. The estimation method is a conditional Poisson regression, since the outcomes are all non-negative counts (integers). The reported estimates are expressed as incident-rate ratios (IRR), which exponentiates the estimated coefficient, and so can be interpreted relative to the number 1.0. Values above 1.0 which are statistically significant (t-statistics are included in parentheses in the tables)

[14] These tests are driven by the concern of potentially confounding effects of post-acquisition inventor selection. Inventors or inventor teams successfully collaborating pre-acquisition are potentially more valuable to the post acquisition entities and may have a higher representation in the post-acquisition cohort of inventors. To rule out this alternative explanation for our results, these specifications limit our sample to acquired-firms that did not collaborate with the acquirer before the acquisition date. This analysis also allows us to verify the effect of post-acquisition commingling without the potential persistence effect of pre-acquisition R&D collaboration intensity on post-acquisition innovation.

correspond to positive effects, while values below 1.0 correspond to negative effects. The IRR helps interpret the economic significance of the estimates: a unit increase in an independent variable multiplies the dependent variable by the estimated coefficient. Because our key variable, *commingling intensity*, is expressed as a ratio but does not (in our data) span the entire distribution from zero to one, we express the economic effects throughout as the innovation effect of a standard deviation change in commingling intensity from the mean of the variable's distribution. We only report the estimates of the key variables throughout due to space constraints (all other coefficient estimates are available on request).

Our results indicate that inventor commingling increases innovation outcomes across all specifications, while structural integration reduces innovation outcomes. The only exception to the latter is an increase in *firm cumulative patent classes* for acquired firms that did not perform R&D collaboration with the acquirer prior to the acquisition. We further find that the effect of commingling is more pronounced for firms that do not structurally integrate as exhibited by the IRR of *firm commingling (t-1) * structural integration proxy* which is significantly below 1.0 across specifications. These results provide significant support for H1a and H1b.

Across the specifications, *firm commingling intensity* is strongly positive, both in statistical and economic significance. This result is significant and distinct from the effect of *team knowledge diversity* which is included as a control in models (3), (6) and (9) through (12). To illustrate the economic significance, when all variables on the right-hand side are kept at their mean, and structural integration proxy equals 0, the predicted post acquisition patent stock = 28.6, forward citation stock = 117.7, and cumulative patent classes = 4.3. For a standard deviation increase in firm commingling intensity after the acquisition, the corresponding increases for each of these innovation outcome variables are: 21.5%, 18.8%, and 4.5%, respectively. For acquired firms which are fully integrated, the corresponding increases drop to 16.4%, 12.5%, and 3.7% respectively, illustrating how the effect of post-acquisition commingling on innovation outcomes is more pronounced when the acquired firms are not structurally integrated with the acquirer.

---TABLES 2 & 3 AROUND HERE---

We then move to Table 3, where we use an instrumental variables approach in recognition of the possible endogenous process of firm commingling associated with the results from Table 2. We focus on the introduction (or removal) of direct flight between the two firms as an exogenous shock (outside of managerial control) to the cost of R&D collaboration. Specifically, we use *location connectedness * post-acquisition* as an instrument for the endogenous commingling variable (*location commingling intensity*). In the first two columns, we show that there is a positive and significant relation between the instrumental and variable of interest. This is the first stage of the two stage least squares (2SLS) regression. In the following three columns, for each of the three firm-level innovation outcome variables, we report the results of the 2SLS estimation. The robust positive coefficient of the *location commingling intensity* in the 2SLS estimates suggests that the prior commingling intensity result is not entirely driven by commingling selection effects, but instead points to a commingling treatment effect on innovation. Together the results in Table 2 and Table 3 support H2.

We move to testing H3a/b, the opposing predictions that inventor commingling intensity post-acquisition is associated with less or more innovation performance as compared to the effect of inventor commingling under a pre-acquisition organizational setup. In Table 4, not only do we shift the analysis to the inventor-year level, we match our sampling strategy to test the hypothesis. Specifically, inventors in our sample are those who stayed at the merged firm at least 5 years after the acquisition (following Kapoor & Lim, 2007) from firms which have co-invented patents with their acquirers before the acquisition (and so all of the inventors in the sample worked at firms with commingled patents). In this sample, we can compare inventor innovation profiles under a post-acquisition structure as compared to their own output under a pre-acquisition R&D-collaboration structure.

---TABLE 4 AROUND HERE---

Due to the count nature of the innovation outcomes, we return to Poisson estimation with a variety of fixed effects. All estimates are again expressed as IRRs, with values above (below) 1.0 corresponding to positive (negative) effects. Each specification in Table 4 contains acquiree-inventor fixed effects as well as year fixed effects. The odd columns omit the control variables, while the even specifications include them.

The key variable of interest in the specification is *inventor commingling intensity (t-1) * post-acquisition*. This variable is strongly positive and significantly higher than 1 ($p<0.01$ in all cases). To illustrate the economic significance, when all variables on the right-hand side are kept at their mean after the acquisition, the predicted patent stock = 6.0, forward citation stock = 35.7, and cumulative patent classes = 2.6. For a standard deviation increase in inventor R&D collaboration intensity before the acquisition, the corresponding increases for these variables are 5.8%, 3.8%, and 2.2%, respectively. For a standard deviation increase in inventor commingling intensity post-acquisition, the corresponding increases for these variables are: 7.9%, 5.3%, and 3.0%, respectively. These results confirm H3b (while rejecting H3a), indicating a significant positive effect of post-acquisition commingling on innovation outcomes which also manifests in the fact that the same inventors will be more innovative when commingling post-acquisition as compared to under a pre-acquisition R&D collaboration.

5. Discussion and Conclusion

We introduce the concept of inventor commingling, where inventors from the acquired and acquiring entities collaborate on R&D as a means of improving post-acquisition innovation outcomes. Unlike structural integration, which has been characterized as disruptive in the literature (but necessary in certain instances to achieve task coordination), we show that team commingling increases patent output and scope. Team commingling provides an alternative organizational solution supporting an effective balance when considering independent innovation versus structural integration of the acquired entity. As such, commingling facilitates unsticking and recombining knowledge at both the individual and organizational levels (not just enhancing individual motivation). By exploiting events which exogenously change the ease or difficulty of commingling, we find support for causality running from commingling to innovation outcomes.

5.1 Contributions to Research

We believe this research contribute to the post-acquisition integration literature by identifying a new mechanism of leveraging acquired knowledge and human capital. While the prior literature has focused on centralized organizational design, such as structural integration, we delve into the individual and R&D production team levels of analysis, and implications for firm-level innovation outcomes. We believe this focus on knowledge recombination at the inventor and production team level is novel to the post-acquisition integration literature (and is a separate construct from the typical R&D team composition one, e.g., Aggarwal, et al. (2020)).

While earlier organizational theorists such as Van de Ven et al. (1976) discussed the possibility of group governance as a contrast to typical vertical (hierarchical) relations, this level of decision making and alternatives to vertical governance has been much less discussed in the recent literature. Even more rare is across-level theorizing and analysis in this domain of organizational design, which is unfortunate given the very clear theory in the knowledge-based view of the firm (such as that contained within Kogut & Zander (1992)) as to the different loci of information and know-how contained at the individual, group, and organizational levels of analysis.

Our work suggests that individuals may be the agents of organizational routine "mutation" (to use a term from evolutionary theory) in that they may be the vehicles by which organizations gradually incorporate and recombine different organizational processes and routines, as well as individual know-how for innovation. At the production team level, an intriguing possibility based on the notion of group governance is horizontal governance and orchestration, even when mutual adjustment is necessary due to an interdependent task environment. Future research could delve into this phenomenon in greater depth, especially regarding boundary conditions as to *when* this design might be feasible. Finally, at the firm level, given the importance of managerial control as revealed in our analysis of innovation outcomes of the same inventors operating under the alliance versus merger structures, we infer that the knowledge-based view may be enhanced by incorporating notions of hierarchical (vertical) control. Our hope is that this work contributes to restarting discussion in this literature regarding how these levels of analyses intersect and may influence each other in the context of organizational design for innovation, especially in the case of post-acquisition organization.

Several of the seminal contributions which have been so instrumental to shaping the organizational design literature originated in the context of large, complex organizations in the economy. The locus of innovative effort since that time has shifted away from such complex organizations, however (Arora, et al. 2018), and into the domain of universities and emerging enterprises. In the modern age, through markets for technology, including through the acquisition channel, established firms access startup technology as well as "acqui-hires" and their associated know-how. While the challenge of coordination is still present in such contexts, we argue that unsticking knowledge via inventor collaboration across organizational boundaries which are under common ownership as manifested in post-acquisition commingling carries novel implications.

As a further contrast to the evolving business environment context, the economy at the genesis of the organizational design literature was dominated by manufacturing and production/operations, and the concept of a lengthy (perhaps cradle to grave) career at a large industry incumbent was not unusual. In the digital age, with a knowledge-intensive service economy driving economic growth, and with more "job-hopping" behavior, the possible importance of individuals as the means of storing and transmitting organizational routines is intriguing. Just as the literature on spinoffs asks what knowledge and resources founders bring to their new venture, the possibility of mobile (rank and file) individuals bringing organizational knowledge across contexts, as has been suggested in the employee mobility literature, represents a potentially important mechanism of diffusing and recombining organizational processes.

5.2 Limitations and Future Directions

We would also like to call attention to a number of limitations and interpretational issues with the study. While our instrumental variable analysis provides support for causation from commingling to innovation outputs, we do not address the endogenous nature of acquisition selection itself. To understand possible selection effects or boundary conditions, future research would ideally draw from a broader sample to better understand the role of commingling. Doing so may entail matching individuals and firms on observables to build counterfactual samples for comparison. Another inherent limitation stems from the fact that we take as given post-acquisition inventor mobility (or lack thereof). However, the process governing this choice is likely intentional and selected (from both the inventor and acquirer sides). Among the stayers, organizations may target certain individuals for commingling in ways which are unobserved and unmeasured (a concern which motivated our robustness checks in the empirical analyses). More generally, commingled teams may result from serendipity, managerially-placed organizational design choices (some of which have been discussed in the literature), or even to a degree, self-assembled teams.

As a consequence, future research in this domain would ideally improve our understanding of the antecedents of inventor commingling. Such an examination would necessarily specify the level of analysis of decision-making, choices, and actions, as well as the relevant parties involved. While designing a study spanning conceptual and empirical components would not necessarily be easy, doing so would also help build a bridge between the two main branches of the technology acquisition literature: partner selection versus post acquisition integration studies. A second potential avenue for future work would deepen our understanding of governing inter-organizational collaboration within the context of the knowledge-based view of the firm. By comparing the same individual operating under two alternative organizing regimes (pre-acquisition alliance versus post-acquisition), we found that accessing, unsticking and recombining organizational and individual knowledge may be necessary but not sufficient for inducing the highest level of innovation outcomes. The control and authority piece would seem to go hand-in-hand with the knowledge piece. Going forward, however, there is active debate in the literature about the extent to which organizations could be governed via decentralized means, including the blockchain and using cryptography-based tokens (e.g., Lumineau et al., 2021).

Our hope is that the concepts developed and results reported here will open new avenues for subsequent work on post-acquisition technology integration which is not confined to the autonomy-integration tradeoff, and which take the changing context of innovative industrial activity more into consideration. By doing so, we hope that we develop a more complete picture of the managerial levers to pull to induce superior R&D and innovation outcomes.

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TABLE 1. Focal variable definitions and summary statistics

Firm-year level of analysis			
Variable	***Definition***	***Mean***	***SD***
Firm patents stock	Stock of patents of target firm *i* in year *t*. A patent filed before year *t* will be included in firm *i*'s patent stock if (i) the patent was directly assigned to firm *i*, or (ii) the patent was filed after the acquisition, assigned to the acquirer, and had at least one inventor from firm *i*	32.44	393.10
Firm forward citations stock	Forward citations to firm *i*'s stock of patents within 4 years since patent grant	99.95	1315.10
Firm cumulative patent classes	Number of distinct 3-digit (main) technology classes for firm *i*'s patent stock	4.22	6.76
Firm commingling intensity	Share of patents in firm *i*'s patent stock which were co-invented by inventors of firm *i* and inventors from the acquirer.	0.0132	0.0756
Post-acquisition	Dummy=1 if *t* >= acquired year	0.29	0.45
Firm team knowledge diversity	Average within-team knowledge diversity across all inventor teams which have patented for firm *i* before year *t*. Within-team knowledge diversity is defined following Jaffe's (1986) similarity measure and Aggarwal, Hsu, and Wu (2020).	0.18	0.17
Structural integration proxy	The three-year moving average of the portion of new created patents that are invented by acquired inventors but assigned to the acquirer out of the total number of acquired entity patents. Set to 0 for pre-acquisition periods.	0.051	0.21
Firm cumulative funding rounds	Cumulative number of funding rounds the firm has received up to year *t*	0.44	1.15
Firm cumulative VC investors	Cumulative number of venture capitalists who have invested in the firm up to year *t*	0.44	1.30
Firm technology concentration	Herfindahl index of firm *i*'s patent distribution among 3-digit (main) patent technology classes $Firm\ technology\ concentration_{it} = \sum_{s=1}^{N}(\%\ of\ patents\ in\ tech.class\ s\ in\ firm\ i's\ current\ patent\ stock)^2$	0.45	0.34
Firm inventors	Number of inventors working for firm *i* in year *t*	17.54	129.80
Firm inventor avg cumulative patent counts	Average patenting experience (cumulative patent counts) among firm *i*'s inventors	5.37	6.26
Firm inventor avg cumulative fcitation	Average patenting experience (cumulative patent counts weighted by forward citation) among firm *i*'s inventors	33.53	69.15
Firm inventor avg cumulative patent classes	Average patenting experience (cumulative patent class counts) among firm *i*'s inventors	2.76	1.71
Inventor-year level of analysis			
Inventor patents stock	Inventor *j*'s patent stock in year *t*	5.74	12.22
Inventor forward citations stock	Forward citations to inventor *j*'s patents stock within 4 years since patent grant(s)	30.04	112.10
Inventor cumulative patent classes	Number of distinct 3-digit (main) technology classes to inventor *j*'s patent stock in year *t*	2.63	2.23
Inventor commingling intensity	Share of commingled patents in inventor *j*'s patent stock in year *t*	0.022	0.13
Inventor avg patent complexity	Average complexity measure over the inventors' current patent pool. Patent complexity is defined following Fleming & Sorenson (2001).	515.80	408.00
Inventor team knowledge diversity	The average angular distance between the knowledge experience of the focal inventor and that of other inventors who have co-invented with her	0.22	0.20
Inventor co-located	Dummy=1 if the inventor's current address (registered on the most recent patent document) is located within 100km of the acquirer's R&D center	0.24	0.42
R&D location-year level of analysis			
Location patents stock	An R&D location is defined as a 100km-radius cluster of inventors (addresses) who worked for firm *i* before the deal. Inventor *j* works in location *l* if her residential address locates in this 100km-radius cluster. Location *l*'s patent stock is the pool of patents which are invented by inventors working in location *l* and filed before year *t*.	17.25	111.30
Location forward citations stock	Forward citations to location *l*'s patent stock within 4 years since patent grant(s)	56.72	458.40
Location cumulative patent classes	Number of distinct 3-digit (main) technology classes for location *l*'s patent stock	3.94	4.70
Location commingling intensity	Share of patents in location *l*'s patent stock which were co-invented by inventors working in location *l* and inventors from the acquirer	0.038	0.16
Location team knowledge diversity	Average within-team knowledge diversity across all teams associated with the location *l*'s current patent stock.	0.23	0.17
Location connectedness	Number of acquirer's R&D locations which have direct flights to location *l* in year *t*.	18.99	19.96
Location knowledge relatedness	*Relatedness = overlapped-knowledge-base / total knowledge-base of acquired R&D location* Knowledge base is defined following Ahuja & Katila (2001).	0.13	0.29

TABLE 2. Incident rate ratios of commingling on firm innovation (firm-year level of analysis)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
										Excluding firms having pre-acquisition collaboration		
	Firm patent stock			Firm forward citations stock			Firm cumulative patent classes			Firm patent stock	Firm forward citations stock	Firm cumulative patent classes
Firm commingling intensity (t-1)	9.409*** (18.02)	5.041*** (11.04)	3.604*** (10.02)	7.558*** (12.72)	4.483*** (6.90)	3.252*** (6.05)	1.610*** (9.42)	1.336*** (3.97)	1.342*** (5.70)	31.92*** (10.28)	19.54*** (7.67)	4.567*** (10.07)
Structural integration proxy	0.840*** (-6.37)	0.831*** (-6.55)	0.897*** (-5.77)	0.851*** (-5.18)	0.844*** (-5.38)	0.890*** (-4.66)	0.977*** (-3.51)	0.971*** (-4.53)	1.002 (0.43)	0.97 (-1.54)	0.967 (-1.50)	1.029*** (5.50)
Post-acquisition	1.01 (0.56)	0.999 (-0.06)	1.027* (1.73)	1.02 (0.84)	1.010 (0.41)	1.031 (1.29)	0.997 (1.03)	0.994* (-1.79)	0.995* (-1.74)	1.03 (-1.33)	1.060** (-2.42)	1 (-0.14)
*Firm commingling intensity (t-1) * Structural integration proxy*		0.409*** (-3.13)	0.569** (-2.57)		0.531 (-1.59)	0.480** (-2.13)		0.861* (-1.76)	0.870** (-2.14)	0.190*** (-4.86)	0.205*** (-4.02)	0.357*** (-6.57)
*Firm commingling intensity (t-1) * Post-acquisition*		5.734*** (6.90)	3.775*** (6.45)		3.689*** (3.30)	3.116*** (3.33)		1.503*** (5.23)	1.398*** (5.83)			
Firm team knowledge diversity			2.547*** (6.46)			1.383 (1.61)			1.485*** (13.83)	2.788*** (11.38)	1.926*** (5.61)	1.523*** (14.91)
Firm level controls	N	N	Y	N	N	Y	N	N	Y	Y	Y	Y
Acquiree/Acquirer/Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	94,785	94,785	84,434	86,123	86,123	77,589	94,785	94,785	84,434	78,146	71,338	78,146

*Notes: This table reports exponentiated coefficients (incidence-rate ratios) from conditional Poisson regressions. Values greater (less) than 1.0 represent positive (negative) effects. * p<0.1. ** p<0.05, *** p<0.01. Standard errors are robust & t-statistics are in parentheses. Firms in the firm-year panel are target companies in the Crunchbase acquisition database which are also listed in the PatentsView database and were acquired before 2014. The control variables are listed in Table 1.*

TABLE 3. Instrumental variable regressions of team commingling on innovation (R&D location level of analysis)

	(1)	(2)	(3)	(4)	(5)
	1st stage regression		2SLS regressions		
	Location commingling intensity* 100		Log (location patents stock+1)	Log (location forward citations stock+1)	Log (location cumulative patent classes+1)
*Location connectedness * Post-acquisition*	0.0189***	0.0138***			
	(3.71)	(2.75)			
Post-acquisition	0.220*	-0.303***	-0.00831	-0.0113	-0.0157**
	(1.82)	(-2.58)	(-0.73)	(-0.82)	(-2.54)
*Location commingling intensity (t-1) * Structural integration proxy*			-2.175***	-2.108**	-0.793*
			(-2.95)	(-2.53)	(-1.94)
*Location commingling intensity (t-1) * Post-acquisition*			2.582***	2.375***	1.432***
			(3.51)	(2.81)	(3.43)
Structural integration proxy		0.0743***	-0.0724***	-0.0957***	-0.0480***
		(4.44)	(-4.24)	(-4.51)	(-5.31)
R&D location level team knowledge diversity		8.73***	0.00621	-0.156	0.200***
		(4.89)	(0.05)	(-0.85)	(2.89)
Controls	N	Y	Y	Y	Y
Location & Year fixed effects	Y	Y	Y	Y	Y
Observations	102,864	80,176	80,209	80,209	80,209

*Notes: Reported coefficients and t-statistics (in parentheses) are from 1st stage/2SLS regressions. * p<0.1, ** p<0.05, *** p<0.01. Standard errors are robust. A firm's R&D location is defined as a 50km-radius cluster of the residential addresses of inventors who patented for the firm before the acquisition. There are 7,499 R&D locations associated with 717 acquired companies in the sample. Control variables are listed in Table 1.*

TABLE 4. Incident rate ratios of commingling on inventor innovation (inventor-year level of analysis) for the sample of acquired firms that had pre-acquisition inventor collaboration with acquirer inventors.

	(1)	(2)	(3)	(4)	(5)	(6)
	Inventor patent stock		Inventor forward citations stock		Inventor cumulative patent classes	
*Inventor commingling intensity (t-1) * Post-acquisition*	1.741***	1.486***	1.667***	1.363***	1.176***	1.169***
	(15.56)	(12.77)	(12.21)	(8.11)	(8.37)	(8.39)
Inventor commingling intensity (t-1)	3.337***	3.170***	2.036***	2.140***	1.664***	1.575***
	(23.63)	(25.07)	(11.70)	(12.98)	(19.09)	(17.57)
Post-acquisition	1.025***	1.063***	0.934***	0.949***	1.011***	1.025***
	(9.90)	(22.63)	(-9.15)	(-5.45)	(13.36)	(25.75)
Team diversity (inventor level)		0.850***		0.346***		2.103***
		(-4.11)		(-13.23)		(39.85)
Inventor level controls	N	Y	N	Y	N	Y
Firm-Inventor/Year FEs	Y	Y	Y	Y	Y	Y
Observations	589,680	588,867	529,681	528,912	583,508	582,704

*Notes: This table reports exponentiated coefficients (incidence-rate ratios) from conditional Poisson regressions. Values greater (less) than 1.0 represent positive (negative) effects. * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Standard errors are robust & t-statistics are in parentheses. Note that inventors in this sample are from 493 target companies which collaborated with the acquirer in R&D on at least one patent prior to the acquisition. The total number of inventors working for these acquired entities (based on patent filings) is 54,559, of which 7,118 joined after the transaction and 3,515 started to patent for another company within 5 years after the acquisition. The full sample includes 43,936 inventors observed as working for the target pre-and post-deal. The control variables are listed in Table 1.*