Teams and Bankruptcy

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ABSTRACT

We study the impact of corporate bankruptcies on teams and inventor productivity in the United States. We show that bankruptcy reduces team stability. After a bankruptcy, team inventors produce fewer and less impactful patents, and they are more likely to cease patenting. This points to the loss of team-specific human capital as a cost of resource reallocation through bankruptcy. Our findings also suggest that the labor market values teams and their stability. Past collaboration increases the probability of inventors jointly moving to a new firm after bankruptcy, and the productivity of inventors that relocate together with their team increases.

1. Introduction

Teamwork has become a common way of organizing production, in particular when complex tasks are involved.[1] The creation of new knowledge is a good example of such tasks. While in the 1970's academic economists mainly published single-authored papers, by 2012 the average number of co-authors per top journal publication reached 2.2 (Card and DelaVigna 2013). A similar trend can be observed in corporate innovation: the average number of co-authors per patent filed with the United States Patent and Trademark Office (USPTO) increased from 1.5 to 2.4 between 1975 and 2010 (see Figure 1). Despite the importance of teamwork, there is little systematic evidence on the economic drivers affecting the creation, stability, and dissolution of productive team configurations. Understanding these forces is crucial for the design of corporate and public policies that maximize productivity.[2]

In this paper, we investigate the impact of corporate bankruptcies on team stability and labor productivity. Bankruptcies constitute a structured mechanism through which the economy purges itself of obsolete firms and allocates their constituent parts to alternative and potentially more productive uses.[3] While prior work has analyzed the reallocation of physical and human capital through bankruptcies, we are the first to shed light on the impact of bankruptcies on collaborative relationships and team-specific human capital.[4] We provide this evidence by studying how the reallocation of resources through bankruptcy affects the career and productivity of inventors in the United States. Focusing our analysis on inventors has two crucial advantages: first, inventors tend to work in teams, which permits us to study teamwork and team-specific human capital. Second, inventors are an important category of workers due to their central role

[1] Lazear and Shaw (2007) report that from 1987 to 1996, the share of large firms that employ more than 20 percent of their workers in problem-solving teams rose from 37 to 66 percent. There is evidence that teamwork can be considerably more productive than work in more hierarchical environments (e.g., Hamilton, Nickerson, and Owan 2003; Boning, Ichniowski, and Shaw 2007).

[2] Previous research has shown that deaths of team members are detrimental to the productivity of surviving team members (Azoulay, Zivin, and Wang 2010; Azoulay, Fons-Rosen, and Zivin 2015; and Jaravel, Petkova, and Bell 2018). Although this research is informative for the quantification of the importance of teamwork, additional work is required to inform the design of public and corporate policies that aim to nurture or preserve human capital that is specific to teams.

[3] In reality, this process is imperfect: firms that enter bankruptcy may not always be inefficient, and inefficient firms may not always enter bankruptcy (e.g., White 1989). Furthermore, bankrupt firms may impose negative externalities on non-bankrupt peers (e.g., Bernstein, Colonnelli, Giroud and Iverson 2018, Benmelech, Bergman, Milanez, and Mukharlyamov 2014; Benmelech and Bergman 2011; Birge, Parker, and Yang 2015). Bankruptcy also imposes significant direct and indirect costs on creditors, shareholders, and other stakeholders (e.g., Hortaçsu, Matvos, Syverson, and Venkataraman 2013).

[4] We define team-specific human capital as an intangible asset consisting of common knowledge related to communication, coordination, and problem-solving which is not easily codified or transferable across different groups of workers (see, e.g., Bartel, Beaulieu, Phibbs, and Stone 2014).

in the production of innovation and technological progress, which ultimately determines economic growth (e.g., Romer 1990; Grossman and Helpman 1991; and Aghion and Howitt 1992).

While resources may be used more productively following a bankruptcy, the restructuring process is not deterministic and likely involves various imperfections. In particular, in addition to the potential loss in value to the firm's redeployable capital stock (e.g., due to asset fire sales), bankruptcy may involve some deterioration of organizational and human capital (e.g., Graham, Kim, Li, and Qiu 2016). For example, the failure of a firm may result in ongoing R&D projects to be halted and the knowledge accumulated thus far to be lost. Moreover, workers that invested in organizational or other firm-specific human capital will see the value of those skills diminish. Further, frictions in the post-bankruptcy reallocation of resources across firms may lead capital and labor to be idle for some time or even result in protracted sub-optimal uses. In the case of workers, unemployment spells could also accelerate the depreciation of skills (e.g., Ljungqvist and Sargent 1998).

Even though the impact of bankruptcies on the productivity of the average inventor may be ambiguous, team-specific human capital is likely to be adversely affected by bankruptcy if well-established inventor teams are broken up. It may be difficult for inventors that are used to collaborating in teams to move jointly to a new firm after bankruptcy, because few firms may have the financial slack to hire whole groups of employees of the distressed firm. This problem could be further aggravated due to common industry shocks. Furthermore, the joint relocation of former team-members to new firms may be rendered onerous by transaction and coordination costs.[5] The resulting shock to the structure of teams, or, at the extreme, their outright dissolution, may have negative consequences for the productivity of inventors. This would be especially relevant for inventors that have built up significant team-specific human capital in the past.

To shed light on the impact of bankruptcies on the career and productivity of inventors, as well as on the role that team-specific human capital plays in this context, we employ micro-level data on patenting in the United States. Our setting permits us to follow individual inventors across firms and over time (our sample spans the years 1980 to 2010). We measure inventors' individual productivity, both in terms of quantity (patent counts) and quality (citation-based innovation measures, as well as market estimates of the monetary value of patents). Because we can trace the composition of teams within and across firms, we can distinguish the role of team-specific human capital from that of firm-specific human capital.

We have four main findings. First, on average, corporate bankruptcies have a negative impact on the quantity of patents subsequently produced by affected inventors. This is contrary

[5] For example, individuals could have different geographic preferences, or family circumstances may make it difficult to coordinate a joint relocation. Furthermore, depressed housing markets may impede workers' ability to move to other regions (Brown and Matsa 2017).

to the view that bankruptcies release resources to more productive uses (e.g., Hotchkiss and Mooradian 1998) and is consistent with a large theoretical literature on frictions that limit the efficiency of asset reallocation through bankruptcy (e.g., Gertner and Scharfstein 1991; Aghion, Hart and Moore 1992; Shleifer and Vishny 1992). Interestingly, we find no persistent effects (positive or negative) on the *quality* of innovation as measured with citation-based proxies.

Second, inventors that tend to work in teams—those that have co-authored a higher share of patents with other inventors in the financially distressed firm—experience more negative effects on their productivity post-bankruptcy than inventors that rely less on team production. This suggests that team dissolution is an important, yet previously undocumented, cost associated with the process of resource reallocation through bankruptcies. Furthermore, this finding implies that the negative effects on inventor productivity mentioned above are not (solely) driven by disruptions to R&D and other firm processes during bankruptcy—otherwise the productivity of all workers should be similarly affected by bankruptcy, irrespective of the extent to which they work in teams. We also document that team-dependent inventors are less likely to remain active as inventors (by filing patents) after bankruptcy than those that rely less on teamwork.

Third, inventors that tend to produce in teams are more likely to co-locate with their team members post-bankruptcy. This suggests that the labor market values team-specific human capital and encourages its preservation after the bankruptcy, perhaps because such capital is hard to codify and time-consuming to acquire (e.g., Berman, Down, and Hill 2002; Bartel, Beaulieu, Phibbs, and Stone 2014).

Fourth, we find that inventors that co-locate with their team members after the bankruptcy innovate more, both compared to before the bankruptcy and relative to inventors that do not end up working at the same firm with their teammates. This increase in productivity may arise because teams that are more successful tend to survive. It is also conceivable that the new employer is less financially constrained and is able to direct more resources to the team than the previous employer.

We perform a battery of ancillary tests to assess the robustness of our results. First, we restrict the sample to include only "star" inventors (defined as the top decile of inventors by total number of patents filed between 1980 and 2010). This test alleviates the concern that our findings are driven by unproductive inventors being adversely affected by the bankruptcy-induced separation from a highly productive team member. Furthermore, because "star" inventors file patents frequently, this test also ensures that our results are not driven by measurement error in the timing of recorded firm transitions (we infer inventors' careers from their patenting activity). Second, we show that our results are not driven by the selection of inventors that remain in the firm until the bankruptcy filing. We show that our results hold in a subsample of states where courts strongly enforce non-compete clauses in labor contracts, which severely restrict the ability of workers to leave financially distressed firms. The results also hold when we define as "treated" those inventors that worked at the firm three years prior to the bankruptcy filing, instead of the year prior to the filing, as we do in our main tests. Strategic departures are significantly less common three years prior to the bankruptcy (see Baghai, Silva, Thell, and Vig 2018). Overall, these tests alleviate the concern that our findings are driven by unobservable differences in the quality of inventors. Third, we show that our results are robust to different ways of constructing the sample. Our main sample consists of inventors that at some point during the sample period are "treated," that is, experience a corporate bankruptcy. The results also hold when, instead, we also include in the control group inventors that are never treated. Moreover, while our main tests focus on a sample of public firms, our findings remain qualitatively unchanged when we include in the sample inventors that transition to private firms. Furthermore, our results are unaffected when we restrict the sample to end in 2006, to avoid possible effects of the financial crisis. This also reduces concerns related to the mismeasurement of citations due to truncation (patents applied for and granted towards the end of the sample period have fewer opportunities to be cited). Finally, we perform several variations of our estimation, for example, by including firm-by-year fixed effects, or by using alternative industry definitions. In all cases, our main finding that bankruptcies have a negative impact on the productivity of team-dependent inventors remains statistically and economically significant.

Our study contributes to three strands of the literature. First, we add to the literature that studies the allocation of resources through bankruptcy (e.g., Gertner and Scharfstein 1991; Aghion, Hart, and Moore 1992; Shleifer and Vishny 1992; Benmelech and Bergman 2011; Benmelech, Bergman, Milanez, and Mukharlyamov 2014; Birge, Parker, and Yang 2015; Bernstein, Colonnelli, Giroud, and Iverson 2018; Bernstein, Colonnelli, and Iverson 2017; Iverson 2017; Ma and Wang 2017). We differ from this literature by being the first to study the impact of bankruptcies on teamwork and human capital that is specific to collaborative relationships that do not span the entire firm.

Second, we contribute to the body of research on innovation and its determinants. Previous literature has identified several important macroeconomic drivers of innovation, such as patent law (Moser 2005), labor laws (Acharya, Baghai, and Subramanian 2013), bankruptcy codes (Acharya and Subramanian 2009), and quality of institutions (Donges, Meier, and Silva 2016). At the micro-level, access to finance (e.g., Kortum and Lerner 2000; Gompers and Lerner 2001; Kerr, Lerner and Schoar 2014; Bernstein 2015; Hombert and Matray 2016), investors' tolerance for failure (Tian and Wang 2014), and the organizational structure of firms (Seru 2014) have also been shown to affect innovation. In a recent working paper, Liu, Mao, and Tian (2016) quantify the contribution of individuals versus that of firms as drivers of innovation. We contribute to this literature by providing micro-level evidence of a specific channel—bankruptcy and the subsequent redeployment of team-specific human capital—through which corporate innovation and the process of creative destruction takes place.

Our paper is also related to the work on knowledge production and innovation by Azoulay, Zivin, and Wang (2010), Azoulay, Fons-Rosen, and Zivin (2015), and Jaravel, Petkova, and Bell (2018). These studies report a significant negative effect of co-author deaths on the productivity of academics and inventors. We contribute to this literature by documenting changes in the productivity of inventors whose employers file for bankruptcy. Contrary to the case of deaths, bankruptcies need not lead to the dismantlement of teams. Our work is thus primarily an investigation into the role of bankruptcies and labor market frictions in the preservation of team-specific human capital. We also provide evidence that teams are important economic units in the knowledge production industry that surpass firm boundaries: successful inventor teams survive the disintegration of their "host firms" caused by bankruptcies and may in fact thrive within the successor firms. Our findings are relevant for assessing the relative importance of individual human capital, firm-specific human capital, and team-specific human capital as determinants of innovation.

Third, our study adds to the growing literature that studies the interactions between finance and labor. More specifically, it contributes to the body of research that investigates the labor costs of financial distress (e.g., Brown and Matsa 2016; Baghai, Silva, Thell, and Vig 2018). Our research relates to recent work by Graham, Kim, Li, and Qiu (2016) who, in a sample of manufacturing firms, find that workers' earnings fall when a firm files for bankruptcy and that affected employees are likely to subsequently work fewer hours and leave the firm, industry, and local labor market. Eckbo, Thorburn, and Wang (2016) analyze the careers of CEOs of firms that file for bankruptcy; they find that a large fraction of such CEOs leave the executive labor market and suffer a large drop in the present value of future compensation. Finally, Babina (2015) and Hacamo and Kleiner (2016) document the role of bankruptcies in spurring entrepreneurship.

The remainder of the paper is organized as follows: in Section 2, we describe the data and main variables, Section 3 presents the main results on the impact of bankruptcies on the productivity of inventors, Section 4 analyses labor mobility and inventor careers after a bankruptcy, and Section 5 concludes.

2. Data and variables

2.1 Main data sources

We combine three main data sources: patent data, information on individual inventors' careers, and data on firms' financials (including bankruptcy filings). The NBER patent database contains the application dates of granted patents, as well as information on the technology classes of patents. It also includes information on the *assignee* of the patent, which is typically the firm or subsidiary at which the research is conducted; the identifier corresponding to an assignee is unique and time-invariant. The NBER patent dataset also includes a link to Compustat for patent applications between 1975 and 2006; we use this information to link patent assignees to their corporate parents. For the years 2007 – 2010, we employ the link to Compustat provided in Kogan, Papanikolaou, Seru, and Stoffman (2017). Citations to patents are from Lai, D'Amour, Yu, Sun, and Fleming (2011). In addition to citations-based measures of patent quality, we employ a measure of the economic value of patents derived from the stock price reaction to the announcement of new patent grants; we obtain these data from Kogan, Papanikolaou, Seru, and Stoffman (2017).

The data on individual inventors is from Lai, D'Amour, Yu, Sun, and Fleming (2011). These data are based on information from the USPTO and encompass around 4.2 million patent records and 3.1 million inventors for the period 1975 to 2010. The dataset contains disambiguated inventor names and permits us to track the careers of inventors across firms. In our analysis, the place of employment of the inventor is defined as the firm (Compustat's *gvkey*) that a patent assignee belongs to. For example, an inventor that files a patent with firm A in 1999 and one with firm B in 2000 is designated as an employee of firm A in 1999 and as an employee of firm B in 2000. If more than one year passes between two patent filings, we assume that the employment transition between the two firms occurs at the midpoint between the patent application years.[6] Inventors are included in the sample for their entire active career, defined as the years between their first and last patent filings.

Information on bankruptcy filings is from the UCLA-LoPucki Bankruptcy Research Database. Among other information, this dataset contains all Chapter 11 bankruptcy filings of public U.S. firms with assets larger than $100 million; the information includes the bankruptcy filing date, the Compustat firm identifier (*gvkey*), and it spans the years 1980 to 2015. Finally, our source of corporate financial data is Compustat. We collect data on R&D spending, total assets, cash holdings, earnings, and leverage at the firm level for the period 1980 to 2010.

The final sample covers the period 1980 to 2010 and contains 120 public firms that file for Chapter 11 bankruptcy during this sample period. These firms employ 7007 inventors one year prior to the bankruptcy. Figure 2 depicts the frequency of bankruptcy filings by year. We observe that the early 1990s, the early 2000s, and 2009 are the periods with the largest number of bankruptcy filings. This suggests that resource reallocation through bankruptcies primarily occurs during economic downturns. In Figure 3, we tabulate the bankruptcies by industry. Manufacturing is the industry with largest number of bankruptcies, followed by transportation,

[6] For example, if an inventor has a patent with firm A in 1995 and one with firm B in 2000 and no patents in between, we assume that the inventor is with firm A until 1997 and is employed by firm B from 1998 onwards.

communications, electricity and gas, and by the service industries. Within manufacturing, the top five sectors with the largest number of bankruptcies are (in descending order): industrial and commercial machinery, transportation equipment, electronic and other electrical equipment, primary metal industries, and chemicals and allied products.

2.2 Main variables

To conduct our analysis, we first identify the set of inventors that are directly affected by corporate bankruptcies. With a slight abuse of terminology (given the non-random nature of bankruptcies), we refer to such inventors as "treated." That is, if an inventor is present in at least one bankrupt firm in the year that precedes bankruptcy, the inventor is permanently categorized as being in the treatment group. The variable *Post bankruptcy* is a dummy variable that takes the value of one in the years after the bankruptcy filing for inventors in the treatment group. It takes the value of zero in the year of the bankruptcy filing and before; it is also zero for inventors that were never employed by a bankrupt firm in the year prior to bankruptcy (this group of inventors is used in robustness tests, see Section 3.4.7).

We employ several patent-based proxies for innovation in our analysis.[7] For a given inventor in a given year, the variable *Ln(Citations)* is defined as the natural logarithm of one plus the total number of citations (until 2010) obtained on all patents that the inventor applies for (and that are subsequently granted) in that year. In addition, we also employ the variable *Ln(Patents)*, the natural logarithm of one plus the number of patents applied for by a given inventor in a given year. Citations, our main measure of innovation, reflect the importance of an invention, while the simple count of patents does not distinguish between important and less significant technological discoveries. Our final patent-based measure of innovation is *Ln(Citations per patent)*, the natural logarithm of one plus the average number of citations per patent for all patents that a given inventor applies for in a given year. As an additional way to measure the economic value of innovation, we employ the variable *Ln(Dollar value of patents)*, defined as the natural logarithm of one plus the cumulative dollar value of patents (in millions of nominal U.S. dollars) that an inventor applies for in a given year; the dollar value of each patent is obtained from Kogan, Papanikolaou, Seru, and Stoffman (2017). Following the literature, the year refers to the patent application year, and we only consider patents that are eventually granted (e.g., Hall, Jaffe, and Trajtenberg 2001). Citations are naturally censored because patents applied for in later sample years receive on average fewer citations than patents applied for in earlier years. This concern is addressed in two ways. First, we employ year-by-industry fixed effects in our tests (industry is

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[7] There is a long tradition of using patents as proxies for innovative activity (e.g., Griliches 1981, Pakes and Griliches 1980, and Griliches 1990). Measures using information on citations are particularly well suited to capture the economic importance of an invention (e.g., Hall, Jaffe, and Trajtenberg 2005).

defined at the two-digit SIC level). Second, the variable *Ln(Dollar value of patents)* does not suffer from the truncation problem.[8]

In this study, we are interested not only in the evolution of the productivity of inventors following a bankruptcy, but, more generally, also in the impact of bankruptcies on the careers of affected inventors. For this purpose, we construct the variable *Stop inventing*, an indicator that takes the value of one in the year of the last patent application filed by a given inventor. For each pair of treated inventors that are employed at the same firm in the year prior to bankruptcy, we also create the variable *Move together*, an indicator that takes the value of one if both inventors in the pair jointly move to the same new firm following the bankruptcy. The variable takes the value of zero if both inventors remain at the bankrupt (restructured) firm, or if they move to different firms post-bankruptcy, or if one of them stops inventing. Finally, to study the effect of bankruptcies on the likelihood that inventor teams remain together, we construct the following variable. For each inventor *i* in year *t*, we determine the set of patents filed until year *t-4* and the identity of the co-authors of those patents that also worked with that inventor in the same firm in year *t-4*. The variable *Remain together* is defined as the fraction of the inventors that were both co-authors and coworkers of inventor *i* in year *t-4* and that are still at the same firm in year *t*.[9] This variable is a measure of team stability across inventors and over time.

In terms of explanatory variables, the focus of our analysis is on the role of team-specific human capital and how its loss during bankruptcy subsequently affects the productivity of inventors. We construct two measures that capture different aspects of team-specific human capital. First, *Bankruptcy co-authorships* measures the extent to which an inventor collaborates with others at the firm before its bankruptcy. For an inventor that works at a financially distressed firm one year prior to its bankruptcy filing, this variable measures the total share of that inventor's patents that are co-authored with other inventors that are also employed at that firm in the year before bankruptcy; all co-authorships up to the year before the bankruptcy filing are considered in this calculation. For inventors that are not employed at a financially distressed firm in the year prior to bankruptcy, this variable takes the value of zero. *Bankruptcy co-authorships* is constant within an inventor across time and ranges from zero to one. A value of zero indicates that none of the patents of an inventor are co-authored with other inventors that are also present at the bankrupt firm in the year prior to the bankruptcy filing. At the other extreme, a value of one

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[8] In robustness tests, we perform tests in a sample that ends in 2006, which also alleviates concerns related to the data truncation in our main sample, which ends in 2010 (see Section 3.4.9).

[9] A priori, it is not clear what the best way to measure team stability is; in particular, it is unclear what the length of collaboration is that best describes a stable productive team. We choose four years because it strikes a balance between being long enough to plausibly capture meaningful team-specific human capital, while being short enough to not limit our sample period considerably. We note, however, that the pattern of team stability around bankruptcies that we obtain if we use a three-year period (instead of four years) to define this variable, is similar to that documented in Section 3.2.

denotes that all patents of the inventor are produced with other inventors from the bankrupt firm. Therefore, a higher value of *Bankruptcy co-authorships* indicates a higher level of team-specific human capital in an inventor's innovation production function.

Our second measure of the importance of team production is *Stable team share*; this variable captures the stability of inventor teams affected by bankruptcy. For each inventor that works at the bankrupt firm in the year prior to bankruptcy, this variable measures the fraction of other inventors employed by the same firm in the year prior to bankruptcy that work together with that inventor at the same firm post-bankruptcy. Because simply working at the same firm is unlikely to be informative about the intensity of collaboration, we assign more weight to inventors that tend to patent together. For inventors that are not employed by a bankrupt firm in the year prior to its bankruptcy, this variable takes the value of zero. *Stable team share* thus captures both an intensive and an extensive margin of team stability and team-specific human capital. Formally, this variable is constructed as follows:

$$Stable\ team\ share_i = \frac{\sum_{j=1,i\neq j}^{N_f} \mathbb{1}_{ij}\ Pair\ co-dependence_{ij}}{\sum_{j=1,i\neq j}^{N_f} Pair\ co-dependence_{ij}}$$

where N_f is the set of inventors that were at the financially distressed firm f in the year prior to bankruptcy. For two inventors i and j who were at a bankrupt firm one year prior to the bankruptcy, *Pair co-dependence*$_{ij}$ is defined as the share of patents of inventors i and j that are co-authored by both inventors i and j; it includes all patents of both inventors up to the year before the bankruptcy filing. $\mathbb{1}_{ij}$ is an indicator variable that takes the value of one if after the bankruptcy, inventors i and j are employed by the same new firm.

To measure work experience generally and an inventor's experience with patenting more specifically, we calculate the number of years between the current year and the year of the first patent filed by a given inventor. In our regressions, we include a set of fixed effects for years of experience as a way to capture possible non-linearities in the relationship between inventor productivity and experience (e.g., Bell, Chetty, Jaravel, Petkova, and Van Reenen 2017). In addition, in robustness tests we also employ the variable *Tenure at bankrupt firm*, which, for a treated inventor, is the number of years between the year the inventor joined the firm and the year prior to the bankruptcy filing.

Finally, to control for time-varying factors at the firm level that affect innovation, we include the following control variables in the regressions. *Firm size* is the natural logarithm of total assets; *ROA*, the return on assets, is defined as net income divided by total assets; *R&D intensity* is expenditures on research and development divided by total assets; *Cash ratio* is defined as cash and short term marketable securities divided by total assets; and, finally, *Leverage* is the sum of long term debt and debt in current liabilities divided by total assets. These firm-level control variables are winsorized at the 1st and 99th percentiles. We report summary statistics of these variables in Table 1.

3. Bankruptcies, team-dependence, and productivity

3.1 The impact of bankruptcies on inventor productivity

In this section, we examine how bankruptcies affect the post-bankruptcy productivity of inventors on average. Corporate bankruptcies may be an important stimulant of creative destruction in the economy, as new ideas and ventures displace obsolete firms. Whether this process leads to an increase or a decrease in the productivity of individual inventors depends on whether the negative effects due to the bankruptcy (such as work disruption and loss of firm-specific and team-specific human capital) are outweighed by the gains from allocating the production inputs (labor and capital) to their new uses.

We study the evolution of the productivity of inventors that are directly affected by a bankruptcy. Corporate bankruptcies are staggered in time and occur in most of the sample years (see Figure 2); we can thus use inventors of firms that have not gone bankrupt *yet* as a control group for inventors of firms that are currently filing for bankruptcy. Because all inventors in this sample will at some point experience a bankruptcy event, we are comparing similar firms and inventors to each other.[10] The presence of a control group in our analysis allows us to account for industry-level and macroeconomic dynamics in the evolution of innovation that occur in the absence of bankruptcy. Formally, we use the following regression specification:

$$Ln(Citations)_{ift} = \alpha + \beta_1 \cdot Post\ bankruptcy_{ift} + X_{ift}^{\prime}\gamma + \Psi_f + \mu_i + \varepsilon_{ift}, \qquad (1)$$

where $Ln(Citations)_{ift}$ is the natural logarithm of one plus the number of forward citations of all new patents filed in year t by inventor i in firm f. $Post\ bankruptcy_{ift}$ is an indicator variable that takes the value of one in the years following bankruptcy, and zero in the years prior to bankruptcy.

The regression described by equation (1) further includes the following control variables: Ψ is a vector of firm fixed effects, which account for any time-invariant unobservable firm characteristics that may affect innovation. μ are inventor fixed effects, which we include as a way to control for (time-invariant) differences in inventor characteristics that are unobservable to us. Finally, the matrix X contains the following time-varying control variables: dummies for the number of active years of an inventor, to account for any life-cycle related changes in inventor productivity; *Firm size*; *ROA*; *R&D intensity*; *Cash ratio;* and *Leverage*.[11] The matrix X also includes

[10] In our main sample, all inventors will eventually experience a bankruptcy; this empirical strategy is similar to that of Bertrand and Mullainathan (2003) and Giroud and Mueller (2015), for example. In robustness tests, we also include in the sample inventors that never experience a bankruptcy event (see Section 3.4.7).

[11] In Section 3.4 we report a variation of our regression specification without time-varying controls.

industry–year fixed effects, which permit us to control for a variety of other potential confounding factors, such as the possibility that the incidence of bankruptcies may be higher in industries that are in decline, that the redeployability of human capital post-bankruptcy may vary across industries and time, or that the value of inventor skills is affected by industry dynamics. Standard errors are clustered at the firm level to account for any correlation in error terms within firms.

We present results of these tests in Table 2. The specification reported in column 1 shows that, on average, bankruptcy has a negative effect on innovation productivity. Inventors that experience a bankruptcy event are subject to a drop in citations of roughly 4% relative to what would be expected given industry trends, inventor experience, and other inventor- and firm-level determinants of innovation. Although negative, the coefficient estimate corresponding to the variable *Post bankruptcy* is not statistically significant at conventional levels (the t-statistic is 0.9). The variable *Ln(Citations)* used in the specification reported in column 1 captures both the importance and quality of an innovation, as well as the quantity of patents produced.[12] It is possible, however, that a bankruptcy event affects the quality and quantity of subsequent innovation activity in different ways. For example, inventors may continue to produce patents, but these patents may turn out to be less cited, that is, economically less valuable, when team-specific human capital is lost due to the bankruptcy.

In columns 2 and 3 of Table 2, we examine whether bankruptcy affects the quantity and quality of innovation produced by inventors in different ways. That is, after the bankruptcy, do inventors produce fewer patents, less influential patents, or a mixture of both? To answer this question, we employ the same regression specification as in column 1 (corresponding to equation (1) above), but we consider a different set of dependent variables: *Ln(Patents)*, as a measure of the quantity of innovation output, and *Ln(Citations per patent)*, which measures the quality of patents produced. In column 2, we find that, on average, inventors produce 10% fewer patents in the years after bankruptcy relative to the years prior to bankruptcy. The regression reported in column 3 suggests that, on average, inventors do not experience any substantial change in the quality of their patents in the years after bankruptcy relative to the years prior to bankruptcy: the coefficient associated with the variable *Post bankruptcy* is negative but statistically insignificant.

In the regressions so far, we focused on patent-based measures of innovation productivity. While these are informative, they are imperfect proxies for the economic value of innovation (see Kogan, Papanikolaou, Seru, and Stockman 2017). As an alternative way to capture the impact of bankruptcies on the economic value of innovation produced by treated inventors, we employ the variable *Ln(Dollar value of patents)* in column 4. This measure is based on the stock market reaction

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[12] For example, suppose that an inventor's output changes from one patent per year that receives two citations, to either three patents per year that each receive one citation, or, alternatively, one patent per year that receives three citations. Based on the measure *Ln(Citations)* employed in the regressions reported in column 1 of Table 2, both of these cases would suggest an equivalent increase in innovation output.

to the announcement of new patent grants (see Section 2 for details). We find that inventors that were employed at the bankrupt firm in the year prior to the bankruptcy filing, experience a 3% reduction in the value of their innovation output in their post-bankruptcy career, although the estimate is not statistically significant.

These results suggest that on average, the transaction costs associated with bankruptcies do not lead to a large drop in the productivity of inventors employed by bankrupt firms. This finding complements prior evidence on the effect of bankruptcies on worker human capital. Graham, Kim, Li, and Qiu (2016) report that after bankruptcy, workers experience a large decline in wages. While we do not study compensation, our results are indicative of more modest losses to human capital in the setting we consider. In particular, while we focus on highly skilled, highly mobile workers, Graham et al. study blue-collar workers for whom job loss may have more severe consequences.

3.2 The impact of bankruptcies on team stability

Even though the average effect of bankruptcies on inventor productivity is small and, in most specifications, statistically insignificant, there may be important heterogeneity: some inventors' productivity may be severely negatively affected, while others may even benefit, perhaps because the new employer is less financially constrained. In this regard, one dimension that is likely to be important relates to teams. Innovation does not happen in isolation: team production is an important aspect of innovation (see Figure 1). A bankruptcy is an event that is likely to impact the stability of teams: it may be difficult to retain the composition of a team in the restructuring firm or to transfer all its members to a new firm post-bankruptcy. Instead, some teams may be dissolved in the event of bankruptcy. Although team dissolution may be an optimal outcome in cases where teams are not productive (e.g., Cornelli, Simintzi, and Vig 2016), frictions in the labor market and inefficiencies in the bankruptcy process may result in significant losses of team-specific human capital. For example, the new employer of some of the team members may be financially constrained and may not have the necessary resources to hire the entire team. Furthermore, a joint relocation of several inventors to a new firm requires considerable coordination, which may not be feasible due to individual inventors' idiosyncratic constraints. In that case, a bankruptcy event may lead to the destruction of team-specific human capital and, consequently, to a decline in innovation output of the affected inventors.

We focus on Chapter 11 bankruptcies in our analysis.[13] It is not clear ex ante to which extent this type of reorganization leads to the dissolution of teams. To shed light on the impact of Chapter 11 bankruptcies on team-specific human capital and subsequent inventor productivity,

[13] Only seven of the Chapter 11 bankruptcies in our sample eventually transition into Chapter 7, a number that is too small for a systematic analysis of the differences in outcomes between reorganizations and liquidations.

we test whether these bankruptcies lead to an increase in the likelihood of team break-ups. First, we document that Chapter 11 bankruptcies and the associated financial distress are severe events that are associated with deep changes in the operations of the firm. In Figure 4, we observe that as firms approach bankruptcy, their profitability decreases (Panel A) and their leverage increases (Panel B).[14] In addition, these firms tend to downsize, in terms of both physical assets (Panel C) and number of inventors (Panel D). In fact, the largest drop in the number of inventors employed by bankrupt firms occurs after year *t-1*, suggesting that Chapter 11 bankruptcies may indeed lead to disruptions in the composition of production teams.

Next, we directly analyze the impact of Chapter 11 bankruptcies on team stability. To be specific, we test whether the variable *Remain together* (measuring the share of an inventor's co-authors from four years ago (*t-4*) that are still employed at the same firm today (*t*)) decreases around the bankruptcy event. This would suggest that bankruptcies negatively affect team stability.

Figure 5 provides a graphical visualization of this analysis. We observe a *V*-shaped relation between corporate bankruptcies and team stability. The stability of inventor teams starts to deteriorate three years prior to the bankruptcy and reaches its minimum in the bankruptcy filing year. After the bankruptcy event, inventors seem to start forming new teams (either in the restructured firm or in their new employer). Four years after the bankruptcy date, the stability of inventor teams seems to be restored to values that are similar to those five years before bankruptcy. We confirm this pattern in Table 3. In column 1, we find that, on average, team stability after bankruptcy is no different than team stability before bankruptcy. In column 2, we show that the disruptive effect of bankruptcies on team composition is concentrated in the year of the bankruptcy and the subsequent year. In terms of magnitudes, the coefficients from specification 2 suggest that the fraction of past team members that remain together is lower by six percentage points in the year of the bankruptcy and the year after, which constitutes a 10% reduction in team size relative to the fraction of team members that remain together in a typical year (on average). Note that our estimation in Table 3 likely underestimates the effect of bankruptcy on team stability: these estimates condition on inventors remaining active in patenting. However, we show in Section 4.1 that there is an increased likelihood that inventors stop patenting post bankruptcy.

These results suggest that bankruptcies have a negative impact on team stability, but this effect is temporary and takes place in the years around the bankruptcy filing year. Although inventors seem to be able to join new stable teams soon after the bankruptcy event, the impact on

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[14] Due to the reorganization and renegotiations that take place during bankruptcy, leverage decreases substantially following the bankruptcy filing date.

their productivity may be long lasting, especially if team-specific human capital takes time to build in newly formed inventor teams. We investigate this issue in the next section.

3.3 Team dissolution and the post-bankruptcy productivity of inventors

Having established that Chapter 11 bankruptcies negatively impact the stability of inventor teams, we assess the role that team-specific human capital plays in explaining post-bankruptcy inventor productivity. Our main variable of interest is *Bankruptcy co-authorships*, which measures the degree to which an inventor's innovation output depends on colleagues in the bankrupt firm (see Section 2 for details). A low value of *Bankruptcy co-authorships* indicates that only a small amount of team-specific human capital is likely to be lost in the event of bankruptcy. In contrast, a high value of *Bankruptcy co-authorships* implies high interdependence between the inventors of the bankrupt firm, suggesting that team complementarities may be an important element of inventor productivity.

We first examine this issue graphically in Figure 6. For all four measures of inventor productivity, this figure shows the role of team-specific human capital in explaining innovation around the time of bankruptcy. Panel A measures productivity using *Ln(Citations)*, while Panel B uses *Ln(Patents)*, Panel C employs *Ln(Citations per patent)*, and Panel D uses *Ln(Dollar value of patents)*. On the y-axis, the figure measures changes in innovation per inventor relative to year *t-5* (five years prior to the bankruptcy filing), and on the x-axis, it plots the time relative to the bankruptcy filing year. We observe that from year four before, up to the year of the bankruptcy, inventors with many co-authors in the bankrupt firm are just as productive as they were five years prior to bankruptcy. However, the post-bankruptcy productivity of inventors with many co-authors at the financially distressed firm diminishes significantly relative to the benchmark.

To investigate the role of team-specific human capital for post-bankruptcy inventor productivity in a regression framework, we expand equation (1) by including the variable *Bankruptcy co-authorships*. The coefficient of interest is the one associated with the interaction between *Bankruptcy co-authorships* and *Post bankruptcy*; it measures whether the change in inventor productivity associated with bankruptcy depends on the implied loss of team-specific human capital. If such human capital were irrelevant for productivity or such human capital was not affected by bankruptcy, one would expect to find a coefficient of zero associated with this interaction term. On the other hand, if team-specific human capital is important and bankruptcy affects team stability (as documented in the previous subsection), then inventors whose work relies more on co-authorships within the financially distressed firm will be more negatively affected by the bankruptcy event.

We report results from this analysis in Table 4. Consistent with the view that team-specific human capital is a key determinant of post-bankruptcy inventor productivity, in column 1 we find a significant negative coefficient associated with the interaction term *Post bankruptcy* ×

Bankruptcy co-authorships. In terms of economic magnitude, an inventor who used to co-author all patents with colleagues at the firm filing for bankruptcy (for whom *Bankruptcy co-authorships* takes the value of one) experiences a 17% reduction in citations post-bankruptcy. The coefficients reported in columns 2 and 3 imply that both the quantity as well as the quality of innovation significantly decrease for inventors for whom team complementarities are important. Based on the number of patent filings (column 2) and citations per patent (column 3), an inventor who exclusively patented with co-workers at the bankrupt firm experiences a drop in productivity by 8.4% and 12.6%, respectively. We observe similar effects when innovation is measured using the dollar value of filed patents (column 4).

3.4 Discussion and robustness

3.4.1 Star inventors

One possible concern with our analysis is that firms that go bankrupt may employ inventors that are in many ways different from inventors in firms that do not experience a bankruptcy. In fact, it could be that firms in our sample go bankrupt because of the low quality and quantity of innovation produced by their employees. If, for example, inventors in firms that file for bankruptcy are of worse quality than inventors in firms that are not (yet) financially distressed, then what we are interpreting as a "bankruptcy effect" should instead be attributed to selection. There are several reasons why this is unlikely to be driving our results. First, our regressions reported in Table 4 include inventor fixed effects, which control for any time-invariant unobservable characteristics of inventors, including differences in ability of inventors employed by different firms. Second, we also include industry-year fixed effects to account for the possibility that the value of inventor skills varies across industries and time. This implies that we are not simply capturing the effect of an industry in decline, which may be associated with a reduction in innovation productivity that would occur independently of bankruptcy events. Third, firm fixed effects in our regressions alleviate concerns that firms that go bankrupt and those that do not are fundamentally different from each other, and that these differences are driving our results. Finally, we focus on a sample of "eventually treated" inventors, that is, all inventors in our sample experience a bankruptcy at some point in their career.

To further address the concern that inventors at bankrupt firms may be different, and, in particular, of worse quality than inventors in other firms, we construct a sample of "star inventors." We define such inventors as follows. For all inventors in the dataset (including inventors that never experience a bankruptcy), we calculate the total number of patents granted over the period 1980 – 2010. We then define "star inventors" as those that belong to the top decile of inventors in terms of number of granted patents. If low quality inventors drove some of the previously discussed effects, we would not expect our results to hold when we restrict the sample to the set of the most productive inventors. On the other hand, if our results apply equally to all inventors (including star inventors), then we are more likely capturing a general "bankruptcy effect" rather than an effect attributable to heterogeneity in inventor quality.[15] The results, which employ *Ln(Citations)* as the measure of productivity, are reported in column 1 of Table 5 and confirm our findings from earlier tests. We find that star inventors that have co-authored a large share of their patent portfolio with other inventors from the bankrupt firm experience a significant decrease in their innovation productivity post-bankruptcy.

This test also alleviates the concern that our results may be affected by the way we infer inventor careers from their patenting activity. In particular, our methodology could be adding statistical noise to the estimates through the assumption that inventors switch firms at the midpoint of two consecutive patents in different firms. Because "star" inventors effectively file patents almost every year, this problem does not arise here.

3.4.2 Non-compete clauses

An additional selection concern in our setting is that some of the best individual inventors as well as the best teams of inventors may have left by the time the firm files for bankruptcy (Baghai, Silva, Thell, and Vig 2018). In that case, what we interpret as an impact of bankruptcies and team dissolution on inventor productivity may instead be driven by the type of teams that decide to remain in the firm until the bankruptcy filing date.[16]

In column 2 of Table 5, we test whether our results hold when we focus on a subsample of inventors that are employed in US states whose courts strongly enforce non-compete clauses in labor contracts. Non-compete clauses (also called covenants not to compete) are contractual restrictions in employment contracts aimed at limiting an employee's ability to work for a competing firm or to start a competing business. The extent to which these clauses are enforceable differs across US states (for a recent discussion, see Jeffers 2017).[17] In this subsample of inventors, the concern that the best may have endogenously chosen to abandon the firm is diminished, as the best inventors and the best teams are precisely the type of employees that are likely to have a

[15] We note that "star inventors" are over-represented in the sample as they tend to have long careers.

[16] Note that this effect would likely lead us to *underestimate* the "true" effect of team-specific human capital on post-bankruptcy productivity. If good inventors tend to abandon the sinking ship early, yet team-specific human capital is valuable, then good team-reliant inventors would be more likely to stay than good non-team inventors would. This would imply that our tests in Table 4 would be comparing good team-reliant inventors (who may suffer less from team breakup than the average inventor) to bad non-team reliant inventors, suggesting that the actual effect from team dissolution may be even bigger absent this selection issue.

[17] In this test, we employ a time-varying state-level index measuring the extent to which non-compete clauses are enforced by courts in a given US state. The index is from Bird and Knopf (2015), who apply the same methodology to the index construction as Garmaise (2011) and extend his index from 1992 back to 1976; the index is available up to 2004, which means that the sample in column 2 of Table 5 covers the years 1980 – 2004. High enforceability states are those where the index is above the sample median, 4.

non-compete clause in their employment contract. Our results remain statistically and economically significant in this subsample. The fact that our results hold in the case of inventors that are contractually unable to leave the firm increases our confidence that our findings are not driven by selection.

3.4.3 Alternative definition of "treated" inventors

To further establish that our results are not being driven by the selection of teams that remain in the bankruptcy firms until one year prior to the filing, we perform an additional variation of our estimation. We define as treated those inventors that were at the firm three years prior to bankruptcy. This group of inventors is less likely to be affected by the strategic selection concern because it may be hard to predict a bankruptcy three years before it takes place. Indeed, previous research has shown that up to three years prior to bankruptcy there is little indication of strong selection in the type of workers that remain or leave firms (Baghai, Silva, Thell, and Vig 2018).

We confirm that our results are robust to this variation in column 3 of Table 5. When we use this alternative treatment group (defined at *t-3*, instead of *t-1* as in our main tests), the interaction between *Post bankruptcy* and *Bankruptcy co-authorships* remains negative and economically and statistically significant, as in our main tests.

Altogether, the evidence in subsections 3.4.1 to 3.4.3 leads us to conclude that the selection of inventor teams that stay at the financially distressed firm until *t-1* is unlikely to be the driver of our main finding that team dissolution caused by the bankruptcy event is associated with a drop in inventor productivity.

3.4.4 Inventors in private firms

Our main sample is restricted to public firms, for which a set of time-varying firm characteristics is available from Compustat. We obtain (qualitatively and quantitatively) similar results when we track inventors across public *as well as* private firms. Due to the absence of financial information for private firms, this test, which is reported in column 4 of Table 5, does not control for time-varying firm-level determinants of innovation.

3.4.5 Team-specific human capital versus firm-specific human capital

We employ corporate bankruptcies as a laboratory for our study for two reasons: first, bankruptcies are important corporate events that have the potential to be significant catalysts of the process of creative destruction in the economy by affecting the allocation of resources and the organization of production. Second, bankruptcies act as a shock to the structure of research and development teams. Because this shock affects not only team stability but also other aspects of the firm, a concern that may arise is that what we attribute to team-specific human capital may instead be driven by firm-specific human capital. That is, while a bankruptcy may indeed result in the breaking up of successful innovator teams, the reduction in inventor productivity post-bankruptcy may primarily stem from a loss of firm-specific human capital experienced by such inventors (such as the familiarity with firm-specific software or other complementarities between the inventor and the organization's assets). Moreover, because bankruptcies may lead to the dissolution of the firm, any organizational capital may also be lost around the time of the bankruptcy filing (e.g., Eisfeldt and Papanikolau 2013).

We believe that our tests effectively separate the impact of the bankruptcy-induced disruption to firm-specific human capital from the role played by team-specific human capital. The average effect on innovation attributable to firm-specific human capital and organizational capital is captured by the variable *Post bankruptcy* in our regressions. Furthermore, we note that firm-specific human capital or organizational capital that is shared by all inventors within the firm should not affect our team variable, *Bankruptcy co-authorships*. With this measure of team-specific human capital, we are identifying the differential effect of team dissolution on innovation that is incremental to the average effect of the bankruptcy-induced separation, which is captured by *Post bankruptcy*.

However, one may raise the concern that a higher value of *Bankruptcy co-authorships* may itself proxy for the amount of firm-specific human capital: inventors with longer tenure at a firm may be more likely to co-author more with people at that firm; at the same time, those inventors may build up firm-specific human capital. To ensure that *Bankruptcy co-authorships* is indeed a proxy for team-specific human capital and is not capturing firm-specific human capital, we implement an additional variation of our tests. We add to our regressions the variable *Tenure at bankrupt firm* as a proxy of firm-specific human capital, as well as its interaction with *Post bankruptcy*.[18]

The coefficient estimate on the term *Post bankruptcy* × *Tenure at bankrupt firm* is negative but statistically insignificant (column 5 of Table 5). Importantly, *Post bankruptcy* × *Bankruptcy co-authorships* remains negative and statistically and economically significant. It is also worth noting that in this specification the coefficient on the variable *Post bankruptcy* is positive and statistically significant. This suggests that inventors that (i) do not have co-authorships at the bankrupt firm and that (ii) have not been at that firm for a long time (the average inventor tenure in our sample is 8.6 years) are unlikely to experience drops in productivity following the bankruptcy filing.

3.4.6 Alternative industry definition

In the results in Table 4, we use industry-by-year fixed effects to control for various unobservable factors that drive the evolution of inventor productivity at the industry level. One concern that could arise is that in some cases, the industry of the firm may not be a good representation of the

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[18] Note that our main specification already includes fixed effects for inventor experience to account for the (possibly non-linear) impact of inventor life cycle on productivity.

technology in which different groups of inventors are specializing. For example, it could be that some inventors are working on improvements to established technologies that are well-represented by the current industry definition of the firm, while other inventors within the same firm might be exploring new lines of research that could be more promising in the future. Assigning the same industry to such a diverse group of inventors could lead to biases.

To address this concern, we create measures of the technology class that best represent the innovation activity of each individual inventor. We do so by identifying the technology class (as defined by the Cooperative Patent Classification (CPC) System) in which the inventor has produced the most patents until the current year. We then control for individual inventor technology class-by-year fixed effects. The results, presented in column 6 of Table 5, remain virtually unchanged when we perform this additional robustness test, suggesting that measurement error related to the industry definition is unlikely to drive our findings.

3.4.7 "Never-treated" inventors as control group

To alleviate concerns that firms that file for bankrupt and the inventors that work at these firms are fundamentally different from inventors that never experience bankruptcy, in our main tests, we restrict the sample to inventors that are at some point "treated" during the period 1980 to 2010. We now report estimates obtained when we use the entire population of inventors as a control. Because the control group now includes all inventors that were never employed by a firm one year prior to bankruptcy ("never-treated inventors"), the number of observations increases from about 60,000 to more than three million.[19] The findings remain unchanged: the estimates in column 7 of Table 5 show that after bankruptcy, the decline in inventor productivity is concentrated among the group of inventors that had more team-specific human capital.

3.4.8 Firm-year fixed effects

In our main tests, we control for firm fixed effects to account for any time-invariant firm effect on inventor productivity, as well as time-varying firm controls (*Firm size*, *ROA*, *R&D intensity*, *Cash ratio*, and *Leverage*). However, we note that we find similar results if we employ firm-year fixed effects to account for any time-varying unobservable impact of firms on the productivity of their respective inventors. These results are reported in column 8 of Table 5.

3.4.9 Shortened sample (1980 – 2006)

In our main tests, we make use of the full length of the patent data available from the NBER and study the productivity of inventors between 1980 and 2010. One issue that arises is that patent

[19] Because the UCLA-LoPucki Bankruptcy Research Database only reports information on bankruptcies of firms with $100 million (in 1980 dollars) or more in assets, we restrict the sample of non-bankrupt firms to those whose time-series average and/or median asset values during our sample period also lie above this threshold.

grants and citations are censored in 2010. For that reason, the later years in the sample may be a noisy proxy for the productivity of individual inventors. We address this issue by including industry-by-year fixed effects in all regressions. We now perform an additional test that further addresses this concern.[20] We drop the last four years of the sample and end the analysis in 2006. Since most patent applications are granted within four years (conditional on being successful applications), patent applications that are approved by 2010 should provide an accurate representation of the innovation activity until 2006. In addition, by eliminating the years after 2006 we also ensure that our findings are not driven by the recent financial crisis and the recession that accompanied it. The results, presented in column 9 of Table 5, remain virtually unchanged relative to the estimates obtained with the main sample.

3.4.10 Excluding potentially endogenous controls

Our tests in Table 4 employ a set of time-varying control variables that intend to capture how changes in firm characteristics may affect inventor productivity even in the absence of bankruptcy. However, the inclusion of these control variables raises the concern that we may be controlling away the very effect we intend to document. For example, if a reduction in R&D spending is the way through which bankruptcies affect productivity, our estimates would understate the true impact of bankruptcies on inventor productivity.[21] We address this possibility in column 10 of Table 5 by estimating a regression specification that only includes inventor fixed effects, industry-by-year fixed effects, and experience fixed effects. It leaves out firm fixed effects as well as any other time-varying firm characteristics, which are endogenous (choice) variables. We find that the interaction of *Post bankruptcy* with *Bankruptcy co-authorships* remains statistically significant, and the point estimate increases slightly relative to that in column 1 of Table 4.

3.4.11 Poisson regression

In our main tests, we follow the common practice in the literature on innovation and employ the natural logarithm of patents, citations, citations per patent, and dollar value of patents as our outcome variables in linear regression models.[22] However, we note that we find similar results when we use non-logged variables to estimate a Poisson regression. To facilitate the estimation of the Poisson model, we do not include firm fixed effects and we replace the inventor experience fixed effects with the number of years that an inventor has been active as well as its squared term

[20] Despite this robustness test, we note that it is difficult to envisage a reason for any potential bias to affect inventors with different levels of team-dependence differentially.
[21] We note that it is a priori unclear whether or why this potential bias would differentially affect inventors depending on their level of team-dependence.
[22] See, for example, Bloom, Draca, and Van Reenen (2016), Feng and Jaravel (2017), and Galasso and Schankerman (2015).

(the variables *Experience* and *Experience*^{2}, respectively). These results are reported in column 11 of Table 5. We find qualitatively similar effects using this alternative estimation method.

4. Labor mobility and inventor careers after a bankruptcy

4.1 Inventor career terminations in the shadow of bankruptcy

The results in the previous section conditioned on inventors continuing to innovate post-bankruptcy: an inventor is included in the sample only from the year of the first patent filing to the year of the last patent filed. Yet, after a bankruptcy, some inventors may cease patenting altogether; our previous tests did not specifically take this into account. For example, if an inventor's productivity relies on firm-specific human capital, a corporate bankruptcy may, in the extreme, lead inventors to terminate their innovation career. In addition, if valuable team-specific human capital is destroyed due to the bankruptcy, inventors that are more dependent on teams may be especially prone to leave the profession. We study these questions in this section.

We analyze whether inventors that were employed at a bankrupt firm in the year prior to its bankruptcy filing ("treated" inventors) experience a reduction in the length of their careers as inventors; we employ a linear probability regression framework. The sample encompasses both treated inventors as well as inventors that never experience a corporate bankruptcy. Our outcome variable is *Stop inventing*, a dummy variable which takes the value of one in a given year if an inventor ceases to invent (i.e., stops filing patents) after that year. As before, we control for a host of firm characteristics, as well as industry-year fixed effects in our regressions.[23] Further, we include fixed effects for the number of years that an inventor has been active to account for the fact that older inventors may be more likely to stop inventing than young inventors. In these regressions, in the case of inventors in the "treatment" group, we consider only observations for the period after the bankruptcy filing year: by construction, inventors that worked at a bankrupt firm in the year prior to its bankruptcy filing could not have ended their career before that.

We report the results in Table 6. In column 1, we find that inventors exposed to bankruptcy are more likely to end their career compared to inventors with similar characteristics working at similar firms that do not experience bankruptcy (although this effect is not statistically significant). In column 2, we test whether inventors that are more dependent on team production are more likely to cease patenting. Indeed, our estimates suggest that inventors who produced most of their patents with other inventors at the bankrupt firm are more likely to exit the profession following the bankruptcy. On average, the probability of stopping inventing in a given year is 13%. The

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[23] In these specifications, we do not control for inventor fixed effects because such variables would absorb the cross-sectional variation we are interested in, and we would instead capture a within-inventor *time-series* effect. In addition, we do not include firm fixed effects in these specifications, because our aim is to capture whether being affected by a corporate bankruptcy increases the probability that an inventor ceases to file patents; firm fixed effects would absorb this type of variation of interest.

estimates in column 2 imply that very team reliant inventors (who have produced all their patents with other co-authors at the bankrupt firm) experience a 6.6 percentage point increase (6.6/13 = 51% relative to the sample average) in the likelihood of stopping inventing after the bankruptcy.

It is conceivable that the impact of team-specific human capital on the post-bankruptcy exit probability is stronger in the years immediately following the bankruptcy event. To investigate this, in column 3 of Table 6, we exclude observations from treated inventors more than five years after the bankruptcy filing. We find that the point estimate associated with the interaction term is slightly larger in this specification than in column 2 of Table 6, which indicates that the increase in the probability that team-dependent treated inventors stop innovating may be larger in the immediate aftermath of the bankruptcy.

Overall, the findings in this subsection confirm the importance of team-specific human capital for the post-bankruptcy careers of inventors: the share of patents co-authored with other inventors at the bankrupt firm positively affects the probability that the inventor stops inventing post-bankruptcy. As a caveat, it should be noted that patenting activity may not be a sufficient statistic for the production of innovation. That is, it is possible that inventors affected by bankruptcy do not stop inventing, but only stop patenting, choosing to protect their innovation with secrecy instead. While this is in principle consistent with the tests reported in Table 6, it is unclear why the patenting-secrecy trade-off should be affected by the bankruptcy of the employer as well as by the level of an inventor's pre-bankruptcy team dependence.

4.2 Division sales and post-bankruptcy productivity

During the bankruptcy process, some firms may choose to sell entire divisions or even all substantial assets of the firm. Consequently, some of the respective inventor teams may stay together in the process. One common way for companies to sell entire operations during bankruptcy is through a "363 sale." This is the sale of the assets of an organization under Section 363 of the U.S. Bankruptcy Code. In light of the previous results, one would expect the negative impact of bankruptcies for team players to be more pronounced in the subsample of inventors whose division was not sold as a single unit. On the other hand, inventors whose entire team was acquired by another firm in the course of a "363 sale" may experience only small disruptions to their productivity, if any at all.

In Table 7, we divide the sample into inventors whose division was sold through a 363 sale process (columns 2, 4, 6, and 8) and inventors whose entire division was not acquired during the bankruptcy proceedings (columns 1, 3, 5, and 7). Out of 120 bankruptcies in our sample, 16 involve 363 sales. Reassuringly, and in line with previous results, we observe that when the entire division is acquired there is, on average, no significant difference in the post-bankruptcy productivity of inventors that depend on teams relative to those that do not. Instead, team-dependence and the negative effects of team dissolution on productivity are only substantial when divisions are not acquired as a block.[24]

Although it is likely that team dissolutions are rarer and less severe in the case of 363 sales (in fact, a division may be acquired primarily with a view to hiring its staff; see, e.g., Ouimet and Zarutskie 2016), it is also possible that even when entire divisions are sold many of the division's inventors may be dismissed in the course of its subsequent restructuring and integration within the new corporate owner. In the next subsections, we explicitly study whether past collaboration affects the likelihood of inventors moving together to a new firm, and how such team stability affects the post-bankruptcy productivity of inventors.

4.3 Inventor co-location and post-bankruptcy productivity

The reduction in innovation resulting from the dissolution of teams due to bankruptcy may be limited if inventors move jointly to a new firm. In that case, any team-specific human capital accumulated at the bankrupt firm will continue to be valuable in the new firm. Moreover, because the new employer may direct inventors' efforts to more promising technologies or alleviate financial constraints that may have limited R&D activity at the bankrupt firm, the reallocation of teams may in fact lead to an overall increase in efficiency and in innovation productivity.

To assess how team stability affects inventors' productivity after the bankruptcy of the employer, we test whether the productivity loss suffered by inventors that relied more on team production in the bankrupt firm is mitigated in cases when inventors from the bankrupt firm move together to a new employer. To this end, we employ the variable *Stable team share*, which measures the share of inventors of the bankrupt firm that move jointly to a new firm, weighed by their co-authorships. We first examine this question graphically. Figure 7 plots annual inventor productivity (as measured by number of citations, number of patents, number of citations per patent, and dollar value of patents, in panels A to D, respectively) relative to the year *t-5*. The figure shows that inventors whose team-members co-locate after the bankruptcy experience an increase in innovation (compared to their output five years prior to the bankruptcy filing), relative to inventors whose team is dissolved.

Next, we examine this question in a regression setting. To do this, we additionally interact the term *Post bankruptcy* in equation (1) with the variable *Stable team share*. Table 8 reports the results. As in the previous section, we use four different measures of innovation output:

[24] This result is consistent with the findings in Maksimovic and Phillips (1998, 2001), who document the existence of an active and efficient market for the physical assets of manufacturing firms. Instead of focusing on physical capital, we complement these findings by studying human capital, in particular the redeployability of team-specific human capital.

Ln(Citations) in columns 1 and 2, *Ln(Patents)* in columns 3 and 4, *Ln(Citations per patent)* in columns 5 and 6, and *Ln(Dollar value of patents)* in columns 7 and 8.

Consistent with Figure 7, in column 1, we find that when team-specific human capital is preserved because inventors move jointly to new firms post-bankruptcy, innovation productivity subsequently increases (relative to "treated" inventors whose co-authors do not co-locate with them). In column 2, we include both the interactions of *Post bankruptcy* with *Bankruptcy co-authorships* and with *Stable team share*, respectively. As in Table 4, the interaction of *Post bankruptcy* with *Bankruptcy co-authorships* is negative. Furthermore, the interaction of *Post bankruptcy* with *Stable team share* is positive (albeit not statistically significant). The coefficient estimates (taking into account both interaction terms) suggest that the net effect on innovation for team-reliant inventors of bankrupt firms is positive when a large share of team members co-locates after the bankruptcy. We find a similar pattern when we analyze number of patents (in columns 3 and 4), citations per patent (in columns 5 and 6), and dollar value of patents (in columns 7 and 8). The estimates in column 8, for example, suggest that inventors that have all patents co-authored with other inventors at the bankrupt firm until the year prior to bankruptcy will experience an increase in productivity (as measured by the dollar value of patents) of 21% (0.017-0.08+0.273) if their entire teams move together to a new firm.

Post-bankruptcy co-location is an endogenous decision, as is the decision to acquire an entire division. If only successful teams consisting of prolific inventors remain together after a bankruptcy, then the concern may arise that what we are capturing is a comparison of the productivity of good inventors (after the bankruptcy) to the productivity of average inventors in the pre-bankruptcy firm. This alternative explanation based on selection on time-invariant ability of inventors in bankrupt and non-bankrupt firms cannot account for our findings due to the inclusion of inventor fixed effects in our regressions. However, one can ask whether teams whose productivity is likely to increase in the future are more likely to remain together, while dysfunctional teams may be more likely to be dismantled. In other words, it is conceivable that time-varying unobservables may be the reason that the most valuable teams remain together. Investigating the ability of the labor market to identify and preserve productive team configurations is precisely what we are interested in, in this section. To analyze this issue further, in the next subsection, we directly examine the selection of inventors that move together post-bankruptcy.

4.4 Are well-established inventor teams more likely to co-locate post-bankruptcy?

One question that arises in light of the role played by team-specific human capital for the post-bankruptcy productivity of inventors is whether the labor market recognizes the value of this type of human capital in the sense that, on average, productive team configurations are retained post-bankruptcy. Because inventor productivity is enhanced in the case of joint mobility, one may expect the labor market to attempt to preserve the valuable team-specific human capital, resulting in inventors being hired in groups, instead of individually.

To shed light on this question, we proceed as follows. First, for each bankruptcy event, we create all possible pairs of inventors that are employed by the firm one year prior to bankruptcy, and that remain active post-bankruptcy.[25] We then construct the variable *Pair co-dependence*, a pairwise measure of team-specific human capital, by calculating the share of patents of the pair that is co-authored by its constituent members up to the year prior to the bankruptcy. We use this measure to test whether inventors that work closely together in the firm pre-bankruptcy are more likely to move together to a new employer post-bankruptcy. In this test, each inventor pair enters the sample once and the dependent variable of interest, *Move together*, is an indicator that takes the value of one if the firm to which the two inventors move after the bankruptcy is the same for both inventors in the pair.

Results are reported in Table 9. Column 1 reports the coefficients from a regression specification without any controls, while the specification reproduced in column 2 includes fixed effects for each bankrupt firm. Consistent with the conjecture that the labor market recognizes the importance of team-specific human capital, we find that in cases where co-authorships are important, inventors are indeed more likely to move together to the same firm after the bankruptcy. In terms of magnitude, the coefficient reported in column 2 implies that an inventor pair that has produced all patents together pre-bankruptcy is 3% more likely to co-locate than a pair that has no co-authored patents, and for whom separation is likely to have a negligent impact on productivity (according to our previous analyses reported in Table 4). This number represents about two-thirds of a standard deviation of *Move together*.

For workers involved in bankruptcies close to the end of the sample we, as econometricians, may not have enough time to observe their joint-location decisions, as those career switches are likely to occur after 2010. In that case, we could be biasing our estimates by wrongly assuming that team-dependent inventors do not move together, even if they eventually do. To address this possibility, in columns 3 and 4 of Table 9, we redo the analysis of columns 1 and 2, but consider only inventors whose firm filed for bankruptcy until the year 2000, giving us at least 10 years of subsequent data to identify joint mobility. The results confirm the findings of columns 1 and 2. In addition, we note that the coefficients in columns 3 and 4 are slightly larger than those in columns 1 and 2, indicating that joint mobility does not happen immediately, and may take time to materialize.

The results in this subsection could be driven by two non-mutually exclusive mechanisms. On the one hand, it could be that corporate acquirers understand the value of team production and acquire entire divisions through a 363 sale. On the other hand, teams of inventors may be able

[25] For example, a firm with four inventors has six possible inventor pairs.

to relocate jointly, even in the absence of a division sale, if the labor market places value on team-specific human capital and is able to preserve it. In an attempt to disentangle whether it is the market for corporate control or the labor market that promotes the preservation of productive team configurations, we do an additional test in columns 5 and 6 of Table 9. We exclude from the sample all pairs of inventors whose firm was involved in a "363 sale". The results show that the labor market has an important role in maintaining productive inventor constellations. When we focus on the subsample of inventor pairs whose division was not acquired, the point estimates are similar in magnitude as in the full sample (underlying the specifications reported in columns 1 and 2). This suggests that the continuation of past collaboration is facilitated both through the market for corporate control, as well as through matching in the labor market.

5. Conclusion

Innovation is a crucial engine of economic growth and prosperity. Creative destruction is commonly perceived as a key mechanism through which innovation occurs. This makes corporate bankruptcies and the associated flow of resources from failing businesses to growing firms an important area of inquiry.

In this paper, we analyze the impact of corporate bankruptcies on the allocation of resources and the organization of production by tracking the careers and productivity of inventors employed by firms that file for bankruptcy. Many economists highlight the role of general and firm-specific human capital as determinants of productivity (e.g., Becker 1975; Topel 1991). Our study provides evidence that another important aspect to consider in the context of innovation is the existence of complementarities that do not span the entire firm, but that occur at the team level, giving rise to team-specific human capital. We find that team stability (or lack thereof) is a crucial factor in determining whether there is more knowledge creation than destruction when human capital is reallocated through bankruptcy. When teams are dissolved and inventors that had previously worked together part ways, innovation decreases. This effect is mitigated when inventors that have active working relations move together to a different firm post-bankruptcy. In fact, our estimates imply that full preservation of team-specific human capital through joint mobility of the whole inventor team is associated with a subsequent increase in inventor productivity.

The labor market for inventors takes the importance of teams into account: inventors with strong complementarities (as measured by their past joint output) are more likely to be hired together. This points to the existence of market forces that promote and preserve the stability of teams. Our results highlight the importance of team-specific human capital for the production of knowledge in the economy and suggest that the market for corporate control and the labor market promote the efficient continuation of well-attuned inventor teams.

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Table 1: Summary statistics

This table presents summary statistics. *Ln(Citations)* is defined as the natural logarithm of one plus the total number of citations (until 2010) obtained on all patents that a given inventor files in a given year. *Ln(Patents)* is the natural logarithm of one plus the sum of patents applied for (and ultimately granted) by a given inventor in a given year. *Ln(Citations per patent)* is the natural logarithm of one plus the average number of citations per patent for all patents that a given inventor applies for in a given year. *Ln(Dollar value of patents)* is the natural logarithm of one plus the cumulative dollar value of patents (in millions of nominal U.S. dollars) that an inventor applies for in a given year (Kogan, Papanikolaou, Seru, and Stoffman 2017). *Remain together* measures the share of an inventor's co-authors that were at the same firm four years ago, that are still together at the same firm today. *Stop inventing* is a dummy variable which takes the value of one in a given year if an inventor ceases to invent (i.e., stops filing patents) after that year. For each pair of "treated" inventors, *Move together* is a dummy variable that takes the value of one if the two inventors in the pair move to the same new firm after bankruptcy. *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. *Bankruptcy co-authorships* measures the total share of an inventor's patents that are co-authored with other inventors that were also at the bankrupt firm in the year before bankruptcy. *Stable team share* measures the stability of innovation teams post-bankruptcy. *Pair co-dependence* is the share of patents that each possible pair of "treated" inventors has co-authored until bankruptcy. *Experience* is the number of years between the current year and the year of the first patent filing by a given inventor. *Tenure at bankrupt firm* counts the number of years between the current year and the year an inventor first joins the bankrupt firm. *Firm size* is the natural logarithm of total assets. *ROA* is net income divided by total assets. *R&D intensity* is expenditures on research and development divided by total assets. *Cash ratio* is cash and short term investments divided by total assets. *Leverage* is the sum of short and long term debt divided by total assets. The sample spans the period 1980 to 2010. The sample construction and variables are described in detail in Section 2 of the paper and Appendix A.

Variable	Obs.	Mean	SD
Ln(Citations)	57,137	0.582	1.158
Ln(Patents)	57,137	0.321	0.495
Ln(Citations per patent)	57,137	0.490	0.982
Ln(Dollar value of patents)	57,137	0.423	0.982
Remain together	32,878	0.588	0.222
Stop inventing	3,265,381	0.131	0.338
Move together	879,960	0.002	0.045
Post bankruptcy	57,137	0.150	0.357
Bankruptcy co-authorships	57,137	0.117	0.308
Stable team share	57,137	0.011	0.093
Pair co-dependence	879,960	0.002	0.027
Experience	57,137	8.436	7.066
Tenure at bankrupt firm	57,137	8.598	6.809
Firm size	57,137	9.378	2.092
ROA	57,137	-0.037	0.145
R&D intensity	57,137	0.050	0.042
Cash ratio	57,137	0.084	0.077
Leverage	57,137	0.289	0.171

Table 2: The impact of corporate bankruptcies on the productivity of inventors

This table shows the impact of corporate bankruptcies on inventor-level innovation output. Innovation is *Ln(Citations)* in column 1, *Ln(Patents)* in column 2, *Ln(Citations per patent)* in column 3, and *Ln(Dollar value of patents)* in column 4. *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1) Ln(Citations)	(2) Ln(Patents)	(3) Ln(Citations per patent)	(4) Ln(Dollar value of patents)
Post bankruptcy	-0.039	-0.106**	-0.013	-0.029
	(-0.9)	(-2.2)	(-0.4)	(-0.3)
ROA	0.256***	0.169**	0.182**	0.783***
	(2.8)	(2.4)	(2.3)	(3.5)
R&D intensity	-0.532	0.097	-0.420	-1.564
	(-0.8)	(0.3)	(-0.8)	(-1.0)
Cash ratio	-0.527**	-0.114	-0.500**	-0.020
	(-2.1)	(-1.6)	(-2.2)	(-0.1)
Leverage	-0.124	-0.134*	-0.120	-0.033
	(-0.9)	(-1.7)	(-1.0)	(-0.2)
Firm size	0.167***	0.072***	0.119***	0.206***
	(4.9)	(4.7)	(4.2)	(3.4)
Inventor F.E.	Y	Y	Y	Y
Firm F.E.	Y	Y	Y	Y
Industry × Year F.E.	Y	Y	Y	Y
Experience F.E.	Y	Y	Y	Y
Adjusted R^2	0.286	0.368	0.267	0.289
Observations	57,137	57,137	57,137	57,137

Table 3: Team dissolution around corporate bankruptcies

This table shows the impact of corporate bankruptcies on team stability. The dependent variable is *Remain together*, which is the share of an inventor's co-authors from four years ago ($t-4$) that are still employed at the same firm today (t). *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. t_0 *to t+1* is a dummy variable that takes the value of one during the year of the bankruptcy filing (t_0) and the year after (t+1). *t+2 and after* is a dummy variable that takes the value of one from the second year after bankruptcy and onwards. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5% and 10% is market with ***, ** and * respectively.

	(1)	(2)
	Remain together	
Post bankruptcy	0.027	
	(0.9)	
t_0 to t+1		-0.062***
		(-2.7)
t+2 and after		0.044
		(1.2)
ROA	0.113*	0.091*
	(1.9)	(1.7)
R&D intensity	0.042	0.084
	(0.1)	(0.2)
Cash ratio	0.014	0.041
	(0.2)	(0.5)
Leverage	-0.035	-0.054
	(-0.5)	(-0.8)
Firm size	0.028**	0.028**
	(2.0)	(2.2)
Inventor F.E.	Y	Y
Firm F.E.	Y	Y
Industry × Year F.E.	Y	Y
Experience F.E.	Y	Y
Adjusted R^2	0.719	0.723
Observations	32,878	32,878

Table 4: The impact of team dependence on the post-bankruptcy productivity of inventors

This table shows the impact of team dependence on inventor-level innovation output after bankruptcy. Innovation is *Ln(Citations)* in column 1, *Ln(Patents)* in column 2, *Ln(Citations per patent)* in column 3, and *Ln(Dollar value of patents)* in column 4. *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. *Bankruptcy co-authorships* is a measure of the team-specific human capital accumulated at the financially distressed firm by a given inventor. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1) Ln(Citations)	(2) Ln(Patents)	(3) Ln(Citations per patent)	(4) Ln(Dollar value of patents)
Post bankruptcy	0.097	-0.040	0.087	0.065
	(1.4)	(-0.9)	(1.5)	(0.7)
Post bankruptcy × Bankruptcy co-authorships	-0.173***	-0.084***	-0.126**	-0.120***
	(-2.6)	(-5.2)	(-2.2)	(-2.9)
ROA	0.251***	0.167**	0.178**	0.779***
	(2.7)	(2.4)	(2.2)	(3.5)
R&D intensity	-0.533	0.097	-0.421	-1.565
	(-0.8)	(0.3)	(-0.8)	(-1.0)
Cash ratio	-0.526**	-0.114	-0.500**	-0.020
	(-2.1)	(-1.6)	(-2.2)	(-0.1)
Leverage	-0.121	-0.133*	-0.118	-0.032
	(-0.9)	(-1.7)	(-1.0)	(-0.1)
Firm size	0.170***	0.073***	0.121***	0.208***
	(4.9)	(4.8)	(4.3)	(3.4)
Inventor F.E.	Y	Y	Y	Y
Firm F.E.	Y	Y	Y	Y
Industry × Year F.E.	Y	Y	Y	Y
Experience F.E.	Y	Y	Y	Y
Adjusted R^2	0.286	0.368	0.267	0.289
Observations	57,137	57,137	57,137	57,137

Table 5: The impact of team dependence on the post-bankruptcy productivity of inventors: robustness tests

This table examines the robustness of the impact of team dependence on inventor-level productivity after bankruptcy. *Post bankruptcy* is an indicator variable that takes the value of one in the years post bankruptcy, and zero in the years prior to bankruptcy; it always takes the value of zero for inventors that never experienced bankruptcy (column 7). *Bankruptcy co-authorships* is a measure of the team-specific human capital accumulated at the financially distressed firm. In column 1, we restrict the sample to "star inventors," which we define as those that are in the top 10% of inventors in terms of number of filed patents in our sample. In column 2, we focus on the sub-sample of inventors who are located in US states that have high enforcement of non-compete clauses in labor contracts. In column 3, we define as treated those inventors that were at the firm three years prior to bankruptcy. In column 4, we track inventors in public as well as private firms. In column 5, we add inventor's tenure at the bankrupt firm and its interaction with *Post bankruptcy* to our regression specification. In column 6, we control for individual inventor technology class-by-year fixed effects, where technology class is defined by sorting inventors into 9 categories of the Cooperative Patent Classification. In column 7, we include in the control group all the inventors who have not experienced bankruptcy during the sample period. In column 8, we control for firm-year fixed effects. In column 9, the sample is restricted to end in 2006. In column 10, we remove time-varying firm characteristics and firm fixed effects. In column 11, we estimate a Poisson regression. All variables and sample construction are detailed in Section 2 of the paper and Appendix A. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
					Ln(Citations)						Citations
Post bankruptcy	0.191*	0.148*	0.111	-0.031	0.181**	0.08	0.076	0.124	0.118	0.071	0.386***
	(1.7)	(1.8)	(1.5)	(-0.5)	(2.3)	(-1.1)	(1.5)	(0.9)	(1.6)	(0.8)	(2.6)
Post bankruptcy × Bankruptcy co-authorships	-0.316***	-0.144**	-0.127**	-0.128**	-0.189***	-0.176**	-0.139**	-0.156**	-0.163**	-0.182**	-0.599***
	(-2.9)	(-2.3)	(-2.1)	(-2.1)	(-2.9)	(-2.5)	(-2.1)	(-2.3)	(-2.4)	(-2.6)	(-3.6)
Post bankruptcy × Tenure at bankrupt firm					-0.010						
					(-1.6)						
ROA	0.262*	0.300*	0.322***		0.238***	0.101	0.044		0.248***		0.277
	(1.9)	(1.7)	(3.1)		(2.6)	(-1.2)	(1.1)		(2.7)		(1.1)
R&D Intensity	-0.532	0.387	-0.547		-0.577	0.164	0.393***		0.254		0.747
	(-0.7)	(0.4)	(-0.8)		(-0.9)	(-0.3)	(2.8)		(0.4)		(0.8)
Cash Ratio	-0.587*	-0.302	-0.156		-0.515**	-0.392*	0.034		-0.438*		-0.715*
	(-1.8)	(-0.8)	(-0.8)		(-2.1)	(-1.8)	(0.7)		(-1.7)		(-1.7)
Leverage	-0.215	0.121	0.002		-0.134	-0.092	-0.070*		-0.067		0.349
	(-1.6)	(0.6)	(0.0)		(-1.0)	(-1.2)	(-1.7)		(-0.5)		(1.5)
Firm Size	0.206***	0.146**	0.186***		0.169***	0.140***	0.086***		0.184***		0.082***
	(5.0)	(2.6)	(5.8)		(4.9)	(6.0)	(7.3)		(5.2)		(3.2)
Experience											1.560***
											(14.6)
Experience^2											-0.003***
											(-4.3)
Inventor F.E.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm F.E.	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N
Industry × Year F.E.	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y
Firm x Year F.E.	N	N	N	N	N	N	N	Y	N	N	N
Technology Class × Year F.E.	N	N	N	N	N	Y	N	N	N	N	N
Experience F.E.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Adjusted R^2	0.278	0.302	0.284	0.276	0.286	0.281	0.299	0.304	0.294	0.278	-
Observations	26,686	30,169	84,916	66,381	57,137	57,226	3,307,019	57,131	50,682	57,137	44,398

Table 6: The impact of corporate bankruptcies and team dependence on the likelihood that an inventor stops inventing

This table shows the impact of bankruptcies and team dependence on the likelihood that an inventor stops inventing. *Stop inventing* is a dummy variable that takes the value of one in the last year that a given inventor files a patent. *Post bankruptcy* is an indicator variable that takes the value of one in the years post bankruptcy, and zero in the years prior to bankruptcy; it always takes the value of zero for inventors that never experienced bankruptcy. *Bankruptcy co-authorships* is a measure of the team-specific human capital accumulated at the financially distressed firm. All variables and sample construction are detailed in Section 2 of the paper and Appendix A. In these regressions, in the case of inventors in the "treatment" group, we consider only observations for the year after the bankruptcy filing year. In column 3, we further restrict the post-bankruptcy period to four years after the bankruptcy filing. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1)	(2)	(3)
		Stop inventing	
Post bankruptcy	0.031	-0.020**	-0.019
	(1.4)	(-2.2)	(-1.1)
Post bankruptcy × Bankruptcy co-authorships		0.066***	0.079***
		(3.1)	(3.1)
ROA	-0.067***	-0.067***	-0.067***
	(-5.0)	(-5.0)	(-5.0)
R&D intensity	-0.068**	-0.068**	-0.068**
	(-2.4)	(-2.4)	(-2.4)
Cash ratio	-0.029***	-0.029***	-0.029***
	(-3.3)	(-3.3)	(-3.3)
Leverage	-0.007	-0.007	-0.007
	(-0.8)	(-0.8)	(-0.8)
Firm size	0.001	0.001	0.001
	(1.5)	(1.5)	(1.5)
Industry × Year F.E.	Y	Y	Y
Experience F.E.	Y	Y	Y
Adjusted R^2	0.361	0.361	0.361
Observations	3,265,381	3,265,381	3,262,012

Table 7: The impact of team dependence on the productivity of inventors: the role of "363 sales"

This table reports coefficients from regressions studying the impact of team dependence on inventor-level innovation output after bankruptcy; we report results separately for firms that sold entire divisions and firms that did not. Innovation is *Ln(Citations)* in columns 1 and 2, *Ln(Patents)* in columns 3 and 4, *Ln(Citations per patent)* in columns 5 and 6, and *Ln(Dollar value of patents)* in columns 7 and 8. *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. *Bankruptcy co-authorships* is a measure of the team-specific human capital accumulated at the financially distressed firm. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The sample in columns 1, 3, 5, and 7 is restricted to inventors whose entire division was not sold through Section 363 of the US Bankruptcy code, and the sample in columns 2, 4, 6, and 8 is restricted to inventors whose division was sold through a 363 sale. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln(Citations)		Ln(Patents)		Ln(Citations per patent)		Ln(Dollar value of patents)	
	No sale	Sale	No sale	Sale	No sale	Sale	No sale	Sale
Post bankruptcy	0.089	0.449	0.013	-0.121	0.075	0.327	0.148	-0.606
	(1.3)	(1.3)	(0.4)	(-0.5)	(1.2)	(1.0)	(1.6)	(-1.4)
Post bankruptcy × Bankruptcy co-authorships	-0.179***	0.027	-0.072***	0.028	-0.129**	0.066	-0.126***	0.073
	(-2.7)	(0.2)	(-3.8)	(0.4)	(-2.3)	(0.6)	(-3.0)	(0.4)
ROA	0.207**	-0.552	0.074**	-0.095	0.164*	-0.590	0.489***	0.058
	(2.0)	(-1.2)	(2.2)	(-0.6)	(1.8)	(-1.5)	(4.0)	(0.2)
R&D intensity	-0.199	1.510	0.203	0.179	-0.054	1.222	0.094	0.478
	(-0.2)	(1.0)	(0.8)	(0.3)	(-0.1)	(1.0)	(0.1)	(0.4)
Cash ratio	-0.580**	-0.752	-0.108	-0.139	-0.494**	-0.634	-0.127	-0.053
	(-2.2)	(-1.0)	(-1.2)	(-0.5)	(-2.2)	(-0.9)	(-0.6)	(-0.1)
Leverage	-0.156	0.506	-0.018	0.046	-0.137	0.404	-0.132	-0.743
	(-1.0)	(0.8)	(-0.3)	(0.2)	(-1.1)	(0.7)	(-1.0)	(-1.2)
Firm size	0.149***	0.421***	0.080***	0.142**	0.107***	0.366***	0.202***	0.346**
	(4.1)	(3.1)	(6.0)	(2.4)	(3.6)	(3.1)	(3.3)	(2.3)
Inventor F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Firm F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Industry × Year F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Experience F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Adjusted R^2	0.298	0.269	0.351	0.472	0.281	0.255	0.308	0.343
Observations	43,005	14,047	43,005	14,047	43,005	14,047	43,005	14,047

Table 8: The impact of team stability on the productivity of inventors

This table shows the impact of team stability on inventor-level innovation output after bankruptcy. Innovation is *Ln(Citations)* in columns 1 and 2, *Ln(Patents)* in columns 3 and 4, *Ln(Citations per patent)* in columns 5 and 6, and *Ln(Dollar value of patents)* in columns 7 and 8. *Post bankruptcy* is an indicator variable that takes the value of one in the years after bankruptcy, and zero in the years prior to bankruptcy. *Bankruptcy co-authorships* is a measure of the team-specific human capital accumulated at the financially distressed firm. *Stable team share* is a measure of team stability post-bankruptcy. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The t-statistics in parentheses are calculated based on standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10% is market with ***, **, and *, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln(Citations)		Ln(Patents)		Ln(Citations per patent)		Ln(Dollar value of patents)	
Post bankruptcy	-0.055	0.060	-0.116**	-0.062	-0.025	0.059	-0.048	0.017
	(-1.3)	(0.9)	(-2.4)	(-1.4)	(-0.7)	(1.0)	(-0.5)	(0.2)
Post bankruptcy × Bankruptcy co-authorships		-0.142**		-0.066***		-0.104*		-0.080**
		(-2.4)		(-4.4)		(-1.9)		(-2.6)
Post bankruptcy × Stable team share	0.272*	0.214	0.154***	0.127***	0.201*	0.159	0.305***	0.273***
	(1.9)	(1.6)	(3.4)	(3.0)	(1.7)	(1.4)	(2.8)	(2.7)
ROA	0.249***	0.246***	0.165**	0.164**	0.176**	0.175**	0.774***	0.773***
	(2.7)	(2.7)	(2.3)	(2.3)	(2.2)	(2.2)	(3.5)	(3.5)
R&D intensity	-0.562	-0.557	0.080	0.083	-0.443	-0.439	-1.598	-1.595
	(-0.8)	(-0.8)	(0.2)	(0.3)	(-0.8)	(-0.8)	(-1.0)	(-1.0)
Cash ratio	-0.520**	-0.521**	-0.110	-0.111	-0.496**	-0.496**	-0.013	-0.013
	(-2.1)	(-2.1)	(-1.6)	(-1.6)	(-2.2)	(-2.2)	(-0.1)	(-0.1)
Leverage	-0.124	-0.122	-0.134*	-0.133*	-0.120	-0.119	-0.033	-0.032
	(-0.9)	(-0.9)	(-1.7)	(-1.7)	(-1.0)	(-1.0)	(-0.1)	(-0.1)
Firm size	0.167***	0.170***	0.072***	0.073***	0.119***	0.120***	0.206***	0.208***
	(4.9)	(4.9)	(4.7)	(4.8)	(4.2)	(4.3)	(3.4)	(3.4)
Inventor F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Firm F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Industry × Year F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Experience F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Adjusted R^2	0.286	0.286	0.368	0.368	0.267	0.267	0.289	0.289
Observations	57,137	57,137	57,137	57,137	57,137	57,137	57,137	57,137

Table 9: Team-specific human capital and joint mobility of inventors post bankruptcy

This table shows the impact of team-specific human capital on the probability of joint mobility after bankruptcy. *Move together* is a dummy variable that takes the value of one if two inventors move to the same new firm after bankruptcy. *Pair co-dependence* is the share of patents of the inventors in the pair that is co-authored by its constituent members until bankruptcy. In columns 1 and 2, the full set of treated inventor pairs is included; in columns 3 and 4, the sample includes pairs of inventors whose firm went bankrupt between 1980 and 2000; in columns 5 and 6, we exclude from the sample inventors whose division was sold through Section 363 of the US Bankruptcy code. The regression specifications reported in columns 2, 4, and 6, include bankruptcy firm fixed effects. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The t-statistics in parentheses are calculated based on heteroskedasticity-robust standard errors clustered at the firm level. Statistical significance at 1%, 5%, and 10%, is market with ***, **, and *, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Move together					
	Full sample		Until 2000		No sale	
Pair co-dependence	0.041***	0.029***	0.044**	0.034**	0.031**	0.022***
	(3.1)	(3.2)	(2.6)	(2.7)	(2.6)	(2.9)
Firm F.E.	N	Y	N	Y	N	Y
Adjusted R^2	0.001	0.031	0.001	0.039	0.000	0.030
Observations	879,960	879,960	167,602	167,602	776,186	776,186

Figure 1: Team production in corporate innovation over time

This figure shows the evolution of the average number of co-authors per patent between 1975 and 2010. The data are from the NBER Patent Dataset.

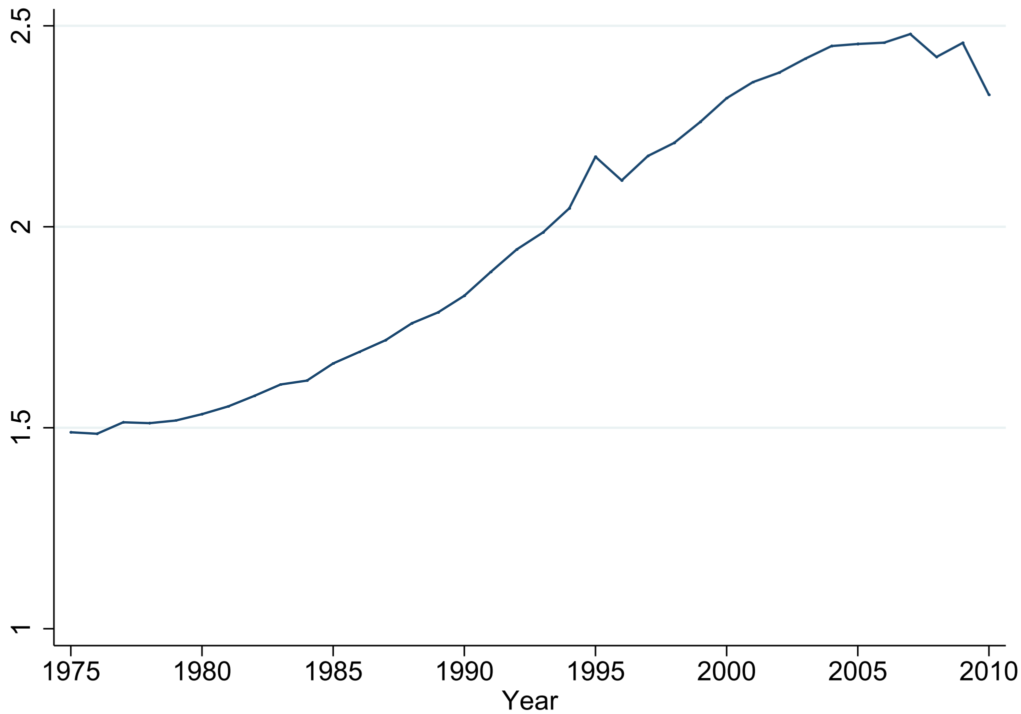


Figure 2: Corporate bankruptcies over time

This figure shows the distribution of corporate bankruptcies by year during the period of our sample (1980 to 2010). Information on bankruptcy filings is from the UCLA-LoPucki Bankruptcy Research Database.

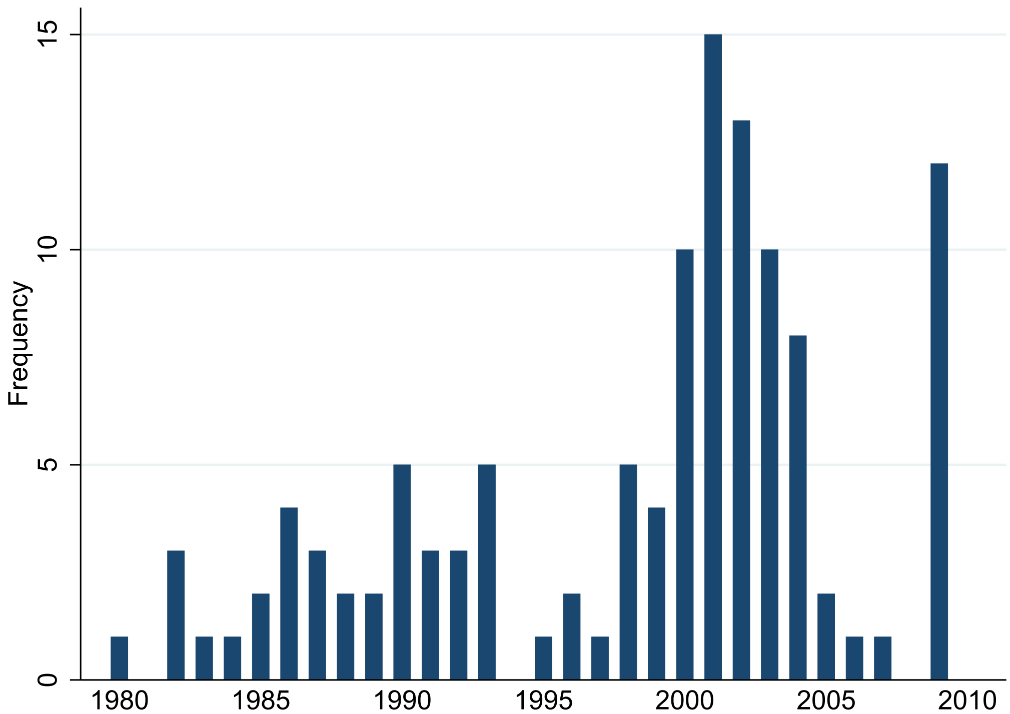


Figure 3: Corporate bankruptcies across industries

This figure shows the distribution of corporate bankruptcies by industry during the period of our sample (1980 to 2010). Information on bankruptcy filings is from the UCLA-LoPucki Bankruptcy Research Database.

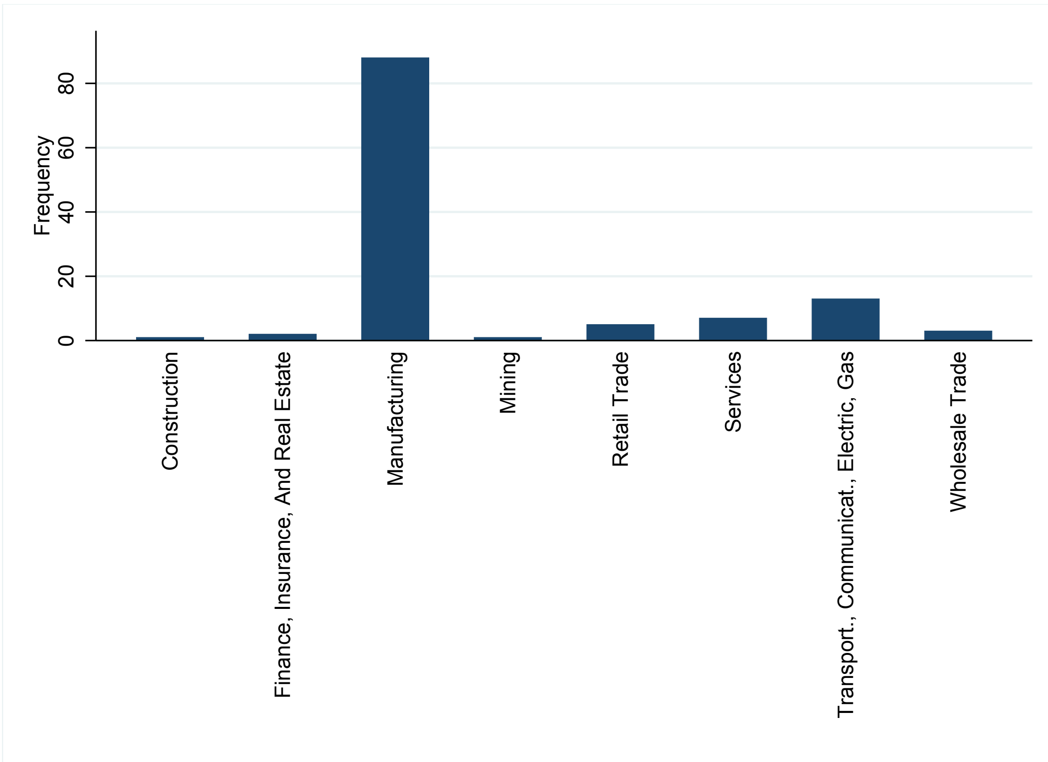


Figure 4: Firm characteristics as firms approach bankruptcy

This figure shows the impact of bankruptcies on firm characteristics. We first estimate the following OLS regression model:

$$Y_{it} = \alpha + \beta \cdot \mathit{Treated}_i \times T_{it} + X'_{it}\gamma + \epsilon_{it}$$

We then plot the coefficients β associated with the interaction between *Treated* and the event-time dummies included in matrix T; we include dummies for the years t-4, t-3, t-2, t-1, 0 (bankruptcy year) relative to the bankruptcy event. These event-time dummies always take the value of zero for firms that do not file bankruptcy during the period 1980-2010. We require treated firms to be present in the sample at time t-5 and exclude any observations after year 0. Y is *ROA* in Panel A, *Leverage* in Panel B, *Firm size* in Panel C, and *Number of inventors*, the total number of inventors employed by a given firm in a given year, in Panel D. The matrix of controls X includes firm fixed effects and industry $\times$ year fixed effects. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The 95% confidence bounds are calculated based on standard errors clustered at the firm level.

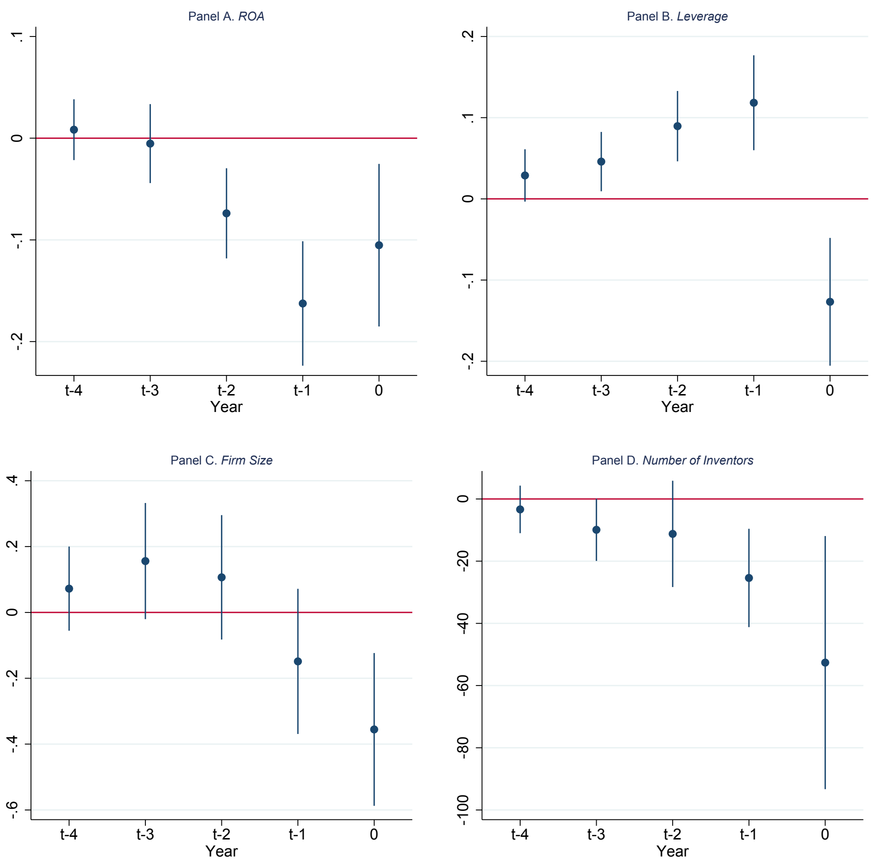


Figure 5: Team dissolution around corporate bankruptcies

This figure shows the impact of bankruptcies on team stability. We first estimate the following OLS regression model:

$$\textit{Remain together}_{it} = \alpha + \beta \cdot T_{it} + X'_{it}\gamma + \epsilon_{it}$$

We then plot the coefficients β associated with the event-time dummies included in matrix T; we include dummies for the years t-4, t-3, t-2, t-1, 0 (bankruptcy year), t+1, t+2, t+3, and t+4 relative to the bankruptcy event. The sample is restricted to "treated" inventors. We require inventors to be present in the sample at time t-5 and exclude any observations after year t+4. The matrix of controls X includes inventor fixed effects, firm fixed effects, industry × year fixed effects, fixed effects for the number of active years of an inventor, *Firm size*, *ROA*, *R&D intensity*, *Cash ratio* and *Leverage*. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The 95% confidence bounds are calculated based on standard errors clustered at the firm level.

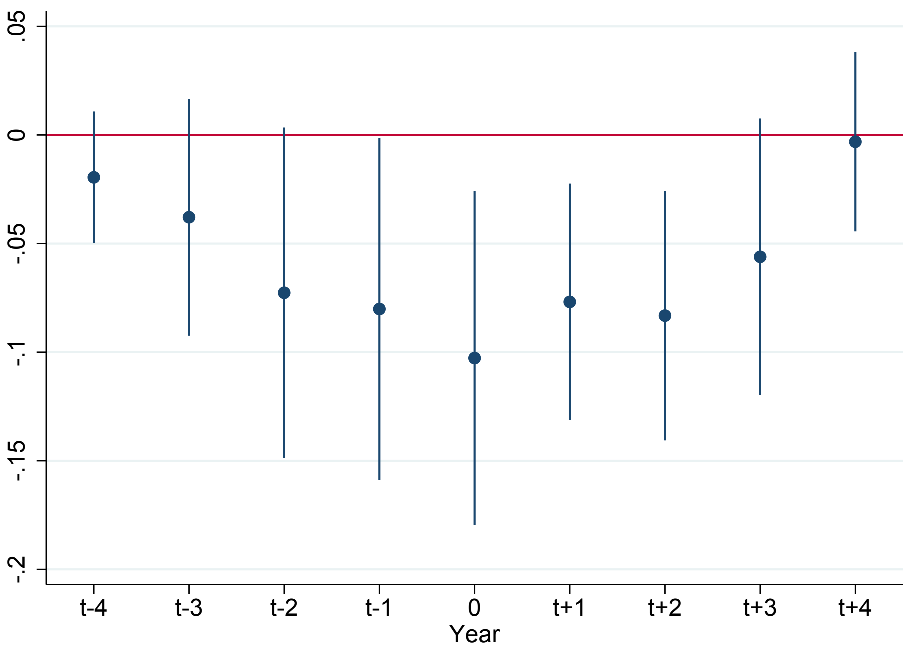


Figure 6: Team-dependence and innovation output around corporate bankruptcies

This figure shows the impact of disruptions to team-specific human capital on the evolution of inventors' productivity around bankruptcy events. We first estimate the following OLS regression model:

$$Innovation_{it} = \alpha + \beta \cdot Treated_i \times T_{it} + \theta \cdot Treated_i \times \textit{Bankruptcy co-authorships}_i \times T_{it} + X_{it}'\gamma + \epsilon_{it}$$

We then plot the coefficients θ associated with the interaction between *Treated* × *Bankruptcy co-authorships* and the event-time dummies included in matrix T; we include dummies for the years t-4, t-3, t-2, t-1, 0 (bankruptcy year), t+1, t+2, t+3, and t+4 relative to the bankruptcy event. The sample is restricted to "treated" inventors. We require inventors to be present in the sample at time t-5 and exclude any observations after year t+4. *Innovation* is *Ln(Citations)* in Panel A, *Ln(Patents)* in Panel B, *Ln(Citations per patent)* in Panel C, and *Ln(Dollar value of patents)* in Panel D. The matrix of controls X includes inventor fixed effects, firm fixed effects, industry × year fixed effects, fixed effects for the number of active years of an inventor, *Firm size*, *ROA*, *R&D intensity*, *Cash ratio*, and *Leverage*. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The 95% confidence bounds are calculated based on standard errors clustered at the firm level.

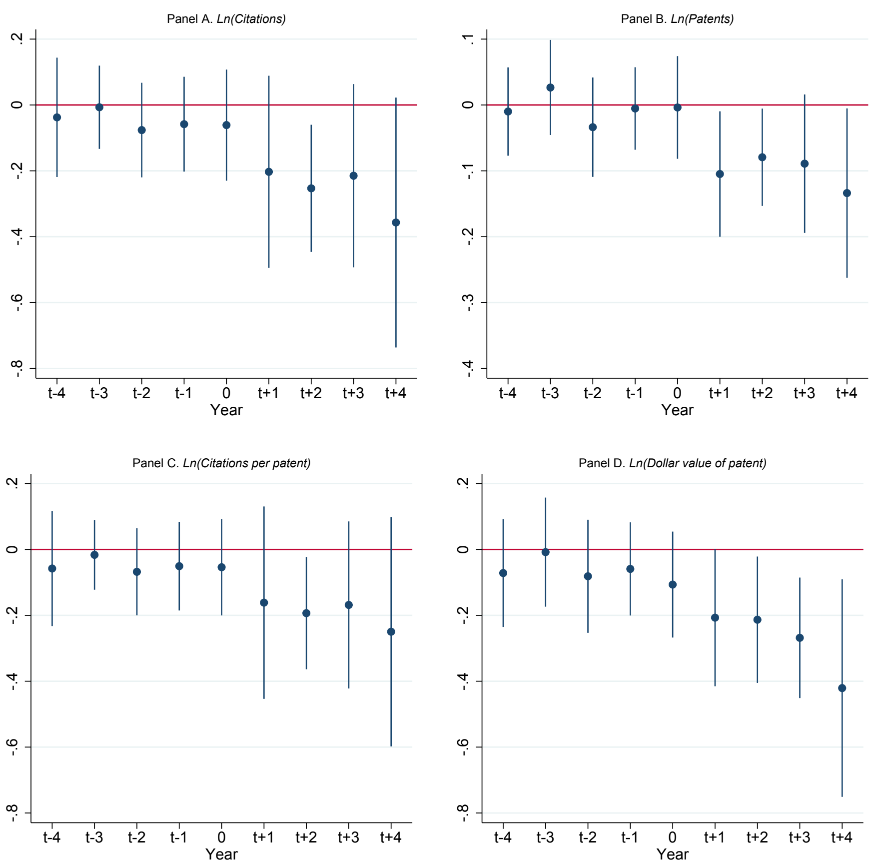
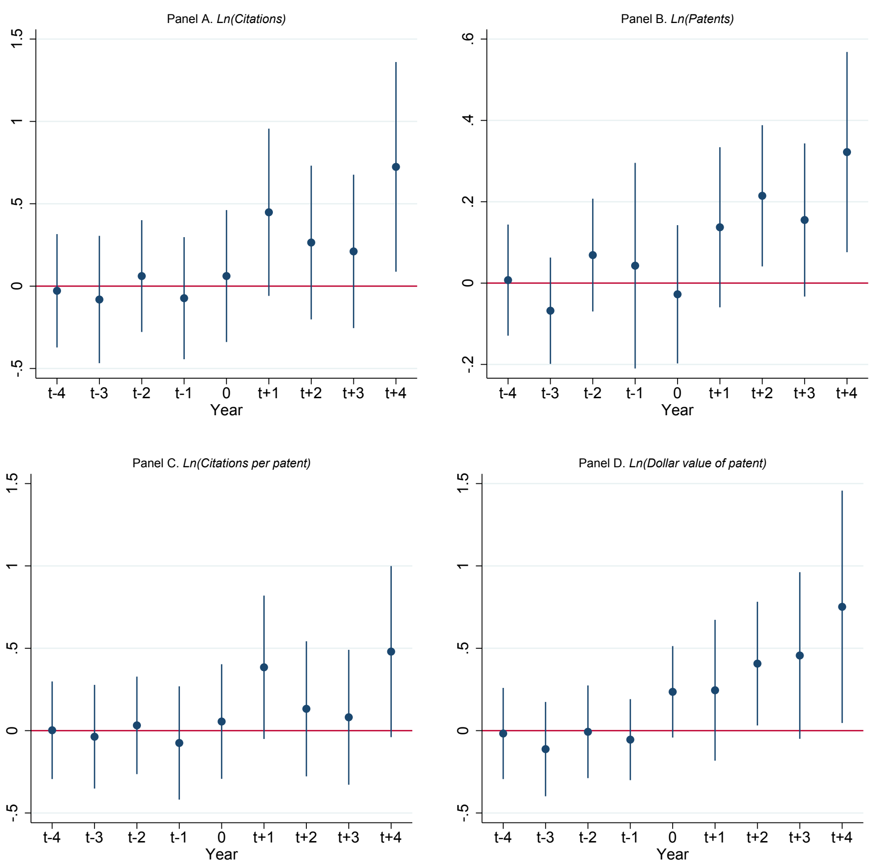


Figure 7: Team stability and innovation output around corporate bankruptcies

This figure shows the impact of team stability on the evolution of inventors' productivity around bankruptcy events. We first estimate the following OLS regression model:

$$Innovation_{it} = \alpha + \beta \cdot Treated_i \times T_{it} + \theta \cdot Treated_i \times Stable\ team\ share_i \times T_{it} + X'_{it}\gamma + \epsilon_{it}$$

We then plot the coefficients θ associated with the interaction between *Treated* $\times$ *Stable team share* and the event-time dummies included in matrix T; we include dummies for the years t-4, t-3, t-2, t-1, 0 (bankruptcy year), t+1, t+2, t+3, and t+4 relative to the bankruptcy event. The sample is restricted to "treated" inventors. We require inventors to be present in the sample at time t-5 and exclude any observations after year t+4. *Innovation* is *Ln(Citations)* in Panel A, *Ln(Patents)* in Panel B, *Ln(Citations per patent)* in Panel C, and *Ln(Dollar value of patents)* in Panel D. The matrix of controls X includes inventor fixed effects, firm fixed effects, industry $\times$ year fixed effects, fixed effects for the number of active years of an inventor, *Firm size*, *ROA*, *R&D intensity*, *Cash ratio*, and *Leverage*. All variables and the sample construction are detailed in Section 2 of the paper and in Appendix A. The 95% confidence bounds are calculated based on standard errors clustered at the firm level.



Appendix A. Variable definitions

A.1. Dependent variables

Ln(Citations) —This variable is our main measure of individual inventor innovation productivity. It is defined as the natural logarithm of one plus the total number of citations (until 2010) obtained on all patents that the inventor applies for (and that are subsequently granted) in that year.

Ln(Patents) —This variable measures the quantity of innovation output produced by individual inventors. It is defined as the natural logarithm of one plus the total number of patents that the inventor applies for (and that are subsequently granted) in that year.

Ln(Citations per patent) —This variable measures the quality of innovation output produced by individual inventors. It is defined as the natural logarithm of one plus the average number of citations per patent for all patents that a given inventor applies for in a given year.

Ln(Dollar value of patents) —This variable is defined as the natural logarithm of one plus the cumulative dollar value of patents (in millions of nominal U.S. dollars) that an inventor applies for in a given year; the dollar value of each patent is obtained from Kogan, Papanikolaou, Seru, and Stoffman (2017).

Remain together —This variable measures the stability of team production over a four year horizon. It is defined as the share of the co-authors of an inventor that were at the same firm four years ago (at $t - 4$), that remain together in the same firm today (in year t).

Stop inventing —This variable captures the end of an innovation career. It is an indicator that takes the value of one in the year of the last patent application filed by a given inventor.

Move together —This variable captures joint relocation. For each pair of treated inventors that are employed at the same firm in the year prior to bankruptcy, this variable is an indicator that takes the value of one if both inventors in the pair jointly move to the same new firm following the bankruptcy.

A.2. Main explanatory variables

Treated —Dummy variable which takes the value of one if an inventor is employed by a firm that files for bankruptcy, in the year before the bankruptcy event. For inventors that are never employed by a firm in the year before it files for bankruptcy, it takes the value of zero.

Post bankruptcy —Dummy variable that takes the value of one in the years after the bankruptcy filing for inventors in the treatment group. This variable takes the value of zero for years prior to bankruptcy and for inventors that were never employed by a bankrupt firm in the year prior to bankruptcy.

Bankruptcy co-authorships —This variable measures the extent to which an inventor collaborates with others at the firm before its bankruptcy. For an inventor that works at a financially distressed firm one year prior to its bankruptcy filing, this variable measures the total share of that inventor's patents that are co-authored with other inventors that are also employed at that firm in the year before bankruptcy; all co-authorships up to the year before the bankruptcy filing are considered in this calculation. For inventors that are never employed by a financially distressed firm in the year prior to bankruptcy, this variable takes the value of zero.

Stable team share —This variable captures the stability of inventor teams affected by bankruptcy. For each inventor that works at the bankrupt firm in the year prior to bankruptcy, this variable measures the fraction of other inventors employed by the same firm in the year prior to bankruptcy that move jointly with that inventor to the same new firm post-bankruptcy. Because simply working at the same firm is unlikely to be informative about the intensity of collaboration, we assign more weight to inventors that tend to patent together. For inventors that are not employed by a bankrupt firm in the year prior to its bankruptcy, this variable takes the value of zero. Formally defined as:

$$\textit{Stable team share}_i = \frac{\sum_{j=1, i \neq j}^{N_f} \mathbb{1}_{ij} \textit{Pair co-dependece}_{ij}}{\sum_{j=1, i \neq j}^{N_f} \textit{Pair co-dependece}_{ij}},$$

where *Pair co-dependence* is defined below, and $\mathbb{1}_{ij}$ is an indicator variable that takes the value of one if after the bankruptcy inventors i and j are employed by the same new firm.

Pair co-dependence —For a pair of inventors i and j who both worked at the same firm in the year prior to bankruptcy, this variable is the share of patents of inventors i and j that are co-authored by both inventors. It includes all patents of both inventors up to the year before bankruptcy filing.

A.3. Inventor- and firm-level control variables

Experience —The number of years between the current year and the year of the first patent filed by a given inventor.

Tenure at bankrupt firm —For a treated inventor, this variable is defined as the number of years between the year the inventor joined the firm and the year prior to the bankruptcy filing.

Firm size —Defined as the natural logarithm of total assets.

ROA —Defined as net income divided by total assets.

R&D intensity —Defined as expenditures on research and development divided by total assets.

Cash ratio —Defined as cash and short term marketable securities divided by total assets.

Leverage —Defined as the sum of long term debt and debt in current liabilities divided by total assets.