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Public-to-Private Buyouts and Innovation

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We study the effect of public-to-private buyout transactions on investments in innovation using an international sample over the 1997–2017 period. We use patent counts and citations to proxy for the quantity, quality and economic importance of innovation. Our results are based on time analysis and matched sample regressions. The data indicate that buyouts are associated with a significant reduction in patents and patent citations, including a reduction in radical (i.e. more scientific) patents. When we split the sample into institutional and management buyouts, the negative effect of buyouts is confirmed only for institutional buyouts. This suggests that only institutional buyouts prevent target firms from adopting long-term investments. This finding is confirmed by reductions in innovator employment and innovation efficiency subsequent to going private. Moreover, the data indicate that the negative effect is most prevalent for transactions where the cost of the deal's debt financing is higher than that of the debt post-buyout. We rule out some alternative explanations for these findings, including but not limited to outliers, truncation bias and endogeneity.

Introduction

The global economy has undergone a profound shift in ownership structure over the past few decades. A significant share of firms is now owned by institutional investors from the private equity (PE) industry, and the effect on target firms continues to be debated. PE firms acquire publicly listed firms, delist them and restructure them. Post-buyout transaction, existing theories suggest that, theoretically, target firms' operating performance, investment and productivity should improve (Jensen, 1989). The intuition is straightforward: PE managers are value-adding active investors that put into place efficient incentive and monitoring mechanisms, together with debt discipline, to enhance firm productivity and performance (Ahlers *et al.*, 2017; Amess, Stiebale and Wright, 2016; Cornelli and Karakaş, 2015; Jensen, 1989).

In contrast, however, critics argue that PE firms are transitory organizations (Kaplan, 1991). They have an overly strong focus on projects with short-term payoffs, and tend to reduce investments in long-term projects in order to ensure they can meet their debt-servicing obligations (Rappaport, 1990). One example of the 'dark' side of PE deals is the buyout of Debenhams, a public-to-private deal that took place in 2003 in the UK. This deal generated enormous profits for the PE owners, but it left the firm with massive debt, and its value

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A free video abstract to accompany this article can be found online at: https://www.youtube.com/watch?v=drDjuiv8L-E&feature=youtu.be

plummeted after the IPO.[1] In subsequent years, it was not able to service its debt, and was taken over by its lenders in 2019.[2] Another example is the US$24 billion buyout of Dell Technologies Inc. by PE firm Silver Lake in 2013, which currently stands as the largest technology firm buyout. In this case, the company was in tatters by 2018, with its financial position described as follows:

> Dell Technologies Inc. seems to be taking a Donald Trump-like approach to determining its self-worth: bold statements, and not a lot of information to back them up… Dell is saddled with a boatload of debt and a messy capital structure…[3]

As a result, the industry as a whole, as well as many academics, have begun to question the positive effects of such short-term thinking.[4]

Additional research has explored the effects of taking firms private in buyout transactions, but the empirical evidence is decidedly mixed. In fact, recent evidence has provided some puzzling results about the real outcome of buyout transactions. Several studies show positive effects of buyouts on the productivity and innovation of target firms (Amess, Stiebale and Wright, 2016; Davis *et al.*, 2014; Lerner, Sorensen and Strömberg, 2011); others have questioned the post-buyout results of performance and productivity improvements (Ayash and Rastad, 2017; Ayash and Schütt, 2016; Bharath, Dittmar and Sivadasan, 2014; Cohn, Mills and Towery, 2014; Goergen, O'Sullivan and Wood, 2014a, 2014b; Weir, Jones and Wright, 2015).

With these questions in mind, we revisit how public-to-private buyout transactions impact long-term investments in innovation. Although many papers have studied operating performance, productivity and employment changes post-buyout, more compelling evidence about the overall effect of buyouts on innovation would be instructive. Davis *et al.*'s (2014) influential paper on buyouts and productivity calls particularly for research on deals executed during the most recent buyout wave of 2006–2007 and the post-2008–2009 global financial crisis. The 2006–2007 buyout wave allowed PE firms to exploit cheap access to credit, which may have changed their motives for such transactions. We note that prior work on buyouts and innovation generally preceded the global financial crisis, and focused largely on US and UK data.

In this paper, we use a comprehensive sample of public-to-private buyout transactions, and a dataset that covers the most recent buyout wave and financial crisis. We study two specific transaction types: institutional buyouts (IBOs) and management buyouts (MBOs). In an IBO, the PE fund acquires a controlling interest in the target firm, hires new management and typically exits within 5 years; in an MBO, current management takes a large ownership stake in the company. The goals of the two groups may be very different. IBO investors are mainly focused on delivering returns on the transaction; MBO investors are focused on servicing sustainable debt, as well as on long-term planning.

To study how public-to-private buyouts impact long-term innovation, we use a unique international dataset over the 1997–2017 period. Our measures of innovation are based on patents registered in each country's office, provided by EPO's Worldwide Patent Statistical Database (PATSTAT). The depth of the data allows us to create measures that have not been used before, such as radical innovation and innovation efficiency.

Our tests are based on before–after buyout analysis, with fixed effects and difference-in-differences methodology for buyout and control samples of public firms. We find that buyouts generally reduce investments in innovation, as measured by the number of patents and citations. These effects are quite substantial in terms of quantity and quality.

[1] https://www.ft.com/content/6fd92a0c-437d-11dc-a065-0000779fd2ac.

[2] https://www.ft.com/content/b784e306-5aad-11e9-9dde-7aedca0a081a.

[3] https://www.bloomberg.com/opinion/articles/2018-07-17/dell-dvmt-vmw-buyout-math-doesn-t-compute.

[4] For example, Laurence Fink, the CEO of BlackRock, said in 2015 that: 'The effects of the short-termist phenomenon are troubling (...) In the face of these pressures, more and more corporate leaders have responded with actions that can deliver immediate returns to shareholders, such as buybacks or dividend increases, while underinvesting in innovation, skilled workforces or essential CAPEX necessary to sustain long-term growth.' More recently, Elon Musk failed in his attempt to take Tesla's stock private in an effort to avoid the public pressures of the stock market. Stephen Diamond, associate law professor at Santa Clara University, described him as follows: 'Musk represents the leading edge of an unfortunate Silicon Valley trend: the narcissistic CEO and the board that lacks the gravitas, experience and independence to consider ordinary investors' interests' (https://www.sfchronicle.com/business/article/Tesla-shareholders-reject-move-to-split-CEO-12970015.php).

We observe a 17% post-buyout decline in the number of patents in year 2, and up to 22% by year 3. The drop in quality ranges from 24% to 45%, and is observed mostly in years 2 and 3. When we distinguish between institutional and management buyouts, we find that, in the case of public-to-private buyouts by institutional investors, the effect on innovation remains negative. The analysis of public firms taken private by management is inconclusive.

We find a consistently negative effect following public-to-private buyouts for a sample of firms that engaged in what we refer to as radical innovation (i.e. a higher level of scientific innovation that cites non-patent literature). Furthermore, we test whether target firms become more efficient in terms of innovative activities. We find that innovation efficiency decreases after a public-to-private buyout. We also find that the negative effect depends on PE investors' syndicate size.

We attempt to explain the underlying reasons for the negative effect of buyouts on innovation, and find it is mostly driven by the relative cost of debt. In particular, if the acquirer cannot lock in financing for the buyout transaction at a lower rate than other market participants' cost of debt, it may negatively impact investment and therefore innovation.

This paper contributes to the literature on the effects of ownership changes, and in particular, the effects of buyout transactions on innovation. Lerner, Sorensen and Strömberg (2011) find that innovation increases after leveraged buyouts (LBOs). Their US-based sample extends through 2005, and the vast majority of their deals are private-to-private transactions. Similarly, Amess, Stiebale and Wright (2016) show an increase in innovative activity for their sample of UK deals, although they state that most of the effect comes from private-to-private transactions.

In contrast, our study differs in several key ways. For example, we study public-to-private buyouts, and our sample is international. The distinction between public-to-private and private-to-private deals is important, as previous studies have suggested. However, to date, none has focused on a detailed analysis of public-to-private deals. We also capture a different time span, which covers the global financial crisis and the second LBO wave (2005–2007). We find some evidence that this negative effect of buyouts on innovation exists primarily in the post-2006 period. We provide evidence based on 'time-trend' analysis for the buyout sample, as well as 'difference-in-differences' results for the matched sample, which mitigates potential endogeneity concerns. We also distinguish between MBOs and IBOs, which affect changes in innovation in very different ways.

The rest of this paper is organized as follows. The next section outlines a literature review and develops our hypotheses. The third section discusses our research design, while the fourth section presents the data. Our main results are in the fifth section, followed by additional analyses in the sixth section. The last section concludes.

Literature review and hypothesis development

Prior literature suggests that ownership structure plays an important role in corporate innovation, because it represents the financing choices, governance and incentives of the owners. An early study by Aghion and Tirole (1994) explores the existence of innovation under different structures. Belenzon, Berkovitz and Bolton (2009) suggest that companies choose the corporate form that is the most conducive to undertaking research and development. Many studies have also examined how various ownership forms affect innovation, focusing explicitly on short- versus long-term value creation.

Some research has found that firms may not invest in long-term projects due to short-term performance pressures (Bushee, 1998, 2001; Graham, Harvey and Rajgopal, 2005; Stein, 1988). Owners may expropriate firm resources and impede innovative activities. Manso (2011) suggests that, ideally, organizing and motivating systems should build in a certain amount of tolerance for failure, as well as reward for long-term success. Moreover, Ferreira, Manso and Silva (2012) show that going public is optimal when exploiting existing ideas, and going private is optimal when exploring new ideas. Empirical evidence shows that innovation generally declines after private firms go public (Bernstein, 2015).

Alternatively, some owner types may enhance innovative activities by serving as active monitors, encouraging management to invest in long-term projects (Burkart, Gromb and Panunzi, 1997; Gillan and Starks, 2000; Kahn and Winton, 1998; Shleifer and Vishny, 1986). For example, Aghion, Van Reenen and Zingales (2013) show that institutional ownership is associated with more innovation. Boot and Vladimirov (2018) show that ownership and innovation can even exhibit a U-shaped relationship when we take into account market collusion. This occurs when public ownership nurtures innovation, and where the probability of success is either very low or very high. Financing of innovation also matters. Atanassov, Nanda and Seru (2007) show that public firms that rely on equity or public debt tend to be more innovative.

The buyout transaction is a particular form of ownership change, generally undertaken by PE firms or firm management using a substantial external source of funding (usually debt). Intuitively, the purpose is to restructure the target firm. Investors aim to install more efficient incentive mechanisms and monitoring, and to improve corporate governance and capital structure (Ahlers *et al.*, 2017; Amess, Stiebale and Wright, 2016; Cornelli and Karakaş, 2015; Jensen, 1989; Lerner, Sorensen and Strömberg, 2011).

Several theories motivate the value gains from public-to-private transactions through restructuring activities that theoretically rely on the reduction of shareholder-related agency costs. This agency conflict might impose significant costs on public firm shareholders due to the fact that the manager acting as an agent has decision power and an informational advantage over shareholders (Jensen and Meckling, 1976). The change in ownership should reduce those costs and improve target firm value, performance and productivity.[5]

However, although the intended goals of public-to-private buyouts are to improve target firm performance, the debt burden may ultimately have a negative effect on its long-term investment. Kaplan (1991) states that PE firms are transitory organizations that focus on projects with short-term payoffs while reducing long-term investments. Rappaport (1990) claims that debt discipline and concentrated ownership can impose significant adjustment costs. Debt can dramatically increase the leverage of target firms, and default risk becomes a primary concern. Moreover, financing is often sourced from multiple debt providers, so refinancing becomes more difficult to achieve (Axelson *et al.*, 2013; Colla, Ippolito and Wagner, 2012; Demiroglu and James, 2010; Graham and Leary, 2011).

We distinguish further between IBOs and MBOs, the two buyout types. In the case of IBOs, the PE fund, as the owner, is in fact an intermediary that must provide returns to its investors. PE firms represent limited partners that provide funding, and typically expect to be repaid within 5 to 10 years. Therefore, although the investment search for the PE fund may take 2 to 3 years, the actual turnaround period can last for 3 to 7 years.

Subsequently, PE funds plan exits that might include the return of the target firm to public ownership or a sale to another acquirer. Most exercise that option between the second and fifth year post-buyout (Kaplan, 1991). Thus, PE funds' investment horizons are generally up to 5 years. In general, the effect of IBOs on innovation might be positive due to efficient incentive mechanisms, concentrated monitoring and improvements in corporate governance and capital structure. But short-term turnaround periods and excessive debt pressure might dampen long-term investments in innovation.

MBOs are subject to similar pressures as IBOs, but shareholder intolerance to failure is another factor in these types of deals. Kamoto (2017) shows that it can weaken managerial innovation incentives in public firms. Therefore, going private in an MBO deal releases management from the dismissal risk posed by this factor. Yet, we do not know to what extent the short-termism of investors on managerial innovation incentives affects post-MBO long-term investment. Subsequently, corporate governance issues exacerbated by dispersed ownership may aggravate agency problems.

Thompson and Wright (1995) suggest that, through MBOs, bureaucratic incentives are being replaced by market-based incentives. The reunification of ownership with control after an MBO should motivate owner-managers to maximize profits. In the context of patenting, we thus expect that managers involved in MBOs will be financially motivated to pursue patenting activity if they believe it will maximize profits.

Theory remains somewhat unclear about the actual effect of public-to-private buyout transactions on long-term investment, but the empirical evidence does not offer a compelling answer either. The literature has mostly debated the effects

[5]For a more detailed discussion of value drivers in public-to-private transactions, see the review by Renneboog and Vansteenkiste (2017).

of buyout transactions on operating performance, productivity and employment, with mixed results. We summarize next.

Early evidence based on plant-level data suggests that PE buyouts exhibit positive effects on productivity (Lichtenberg and Siegel, 1990). There is also some evidence of improved operating performance during the first buyout wave (Baker and Wruck, 1989; Kaplan, 1989; Smith, 1990). More recently, Davis *et al.* (2014) show that, while buyouts can lead to job losses, they also tend to bring productivity improvements. Guo, Hotchkiss and Song (2011) find evidence of a positive effect on productivity after a buyout. Similarly, Acharya *et al.* (2012) and Weir, Jones and Wright (2015) find small improvements in operating performance post-LBO for a UK sample, while Bergström, Grubb and Jonsson (2007) and Boucly, Sraer and Thesmar (2011) find larger operating improvements post-LBO for other countries. Harford and Kolasinski (2013) study wealth creation at the time of PE investor exit, and find no evidence for the short-termism view of buyouts.

Other studies, however, present a different view of the effect of buyouts on target firm efficiency. Bharath, Dittmar and Sivadasan (2014) use a US sample and find that going private does not seem to change firm productivity. In fact, they find some evidence of underinvestment. Cohn, Mills and Towery (2014) and Leslie and Oyer (2008), using a sample of US LBOs, find little or no evidence of operating improvements following a buyout. Similarly, Ayash and Schütt (2016) find no economically significant improvement in operating performance following buyouts, and Ayash and Rastad (2017) question productivity improvement claims in prior literature. In a UK buyout context, Goergen, O'Sullivan and Wood (2014a, 2014b) show that the performance and productivity of IBOs tend to decrease post-transaction.

Moreover, the effect of buyouts may depend on investor type, as Ughetto (2010) finds for private-to-private transactions in Europe. There is some evidence that PE IBOs tend to have a negative effect on employment and productivity (Goergen, O'Sullivan and Wood, 2014a, 2014b; Guery *et al.*, 2017), with the opposite effect for MBOs. Kaplan (1989), Smart and Waldfogel (1994) and Smith (1990) all find very large improvements for US MBOs in the 1980s.

The effect of buyouts on innovation has not attracted sufficient attention, however, and there are few empirical tests. Evidence for the UK for 1998–2005 shows that the effect is more pronounced for private-to-private deals (Amess, Stiebale and Wright 2016). Lerner, Sorensen and Strömberg (2011) use a US sample over 1983–2005 and find a positive effect of PE on innovation.

To summarize the theoretical arguments and extant empirical evidence, it is not clear *ex ante* whether public-to-private transactions have a positive or negative effect on innovation. On the one hand, improvements in corporate governance, managerial incentives and discipline should positively impact innovation. On the other hand, the debt burden and short-term constraints imposed on PE investors can significantly hamper innovative activity. The effect may also differ depending on investor type (institutional or management). Ultimately, we leave it as an empirical question.

Research design

Our research design focuses on two sets of results. First, we analyse the 'before–after' time trends for the sample of firms that went private. We compare innovation levels after going private to those exhibited when the firms were public. Second, we implement 'difference-in-differences' (DiD) tests to analyse the changes in innovation of going-private firms compared to a control group of matched firms that remained public.

The 'before–after' methodology

In order to examine the changes within the going-private group, we run the following ordinary least squares (OLS) regression:

$$y_{i,t} = \alpha + \beta_k D_k + \theta \text{ Controls}_{t-1} + FE + \varepsilon_{i,t} \quad (1)$$

where $y_{i,t}$ is the outcome variable (innovation measures), D_k are dummy variables that equal 1 for year k after the buyout transaction (negative values correspond to years before the buyout), 'Controls' is a vector of country characteristics and FE are firm- and year-country fixed effects. The term $\varepsilon_{i,t}$ stands for residual error. The estimated coefficients on betas are the average effect of the buyout transaction for a particular year.

The 'difference-in-differences' methodology

The 'before–after' analysis of innovation for firms that went private is ultimately driven by country-, industry- or firm-related characteristics such as age and size. In order to eliminate this potential source of endogeneity, we form a matched control group for each going-private firm in our sample of buyouts. Similar to the procedure for the going-private firms, we first ensure that the control group firms have patent activity. Then, we select up to five matched control firms that remained public based on country, industry, event year (announcement), age and size. We thus have 'cells' of one going-private firm, and up to five matched controls. We delete 'cells' where the number of control firms is lower than three. We estimate the following regression model:

$$y_{i,t} = \alpha + \delta_k \text{ Buyout} * D_k + \gamma \text{ Buyout} + \beta_k D_k + FEC + \varepsilon_{i,t} \quad (2)$$

where $y_{i,t}$ is the outcome variable (innovation measures) and D_k are dummy variables that equal 1 for year k after the buyout transaction (negative values correspond to years before the buyout). We omit year 0. FEC are 'cell' fixed effects. The term $\varepsilon_{i,t}$ stands for residual error. The estimated coefficients on deltas are the average treatment effect of the buyout transaction for a particular year compared to the control sample.

Data

Sample construction

To establish our sample, we first obtain buyout transactions from the Zephyr database.[6] We only analyse deals where the acquirer bought 100% of the listed target firm. We choose Zephyr because it shares common identities with the Orbis database. We then merge Zephyr and Orbis with the detailed patent data derived PATSTAT, for which Bureau van Dijk has assigned unique applicant firm identifiers.[7] PATSTAT provides data on patent applications filed in over 90 offices around the world. It contains basic bibliographic information, including date of application, date of patent grant, track record of patent citations and inventor identification for each patent application. PATSTAT is published biannually; we use the autumn 2017 edition.

The PATSTAT database covers patents filed in 93 countries. It therefore provides even greater coverage than the National Bureau of Economic Research (NBER) Patent and Citation database, which is compiled from information in the United States Patent and Trademark Office (USPTO) (Moshirian *et al.*, 2019). The USPTO only aggregates patents filed in the USA.

In summary, using databases that share common identifiers allows us to avoid many pitfalls. Both Zephyr and Orbis are provided by the same supplier, Bureau van Dijk, so we can match deal information to firm-level data more accurately. We further match these data with PATSTAT. Then, using PATSTAT data, we can directly measure firms' innovation levels, regardless of where the patent application was filed.

We include all completed buyout transactions from 1997 to 2011 for an international sample of countries that includes Austria, Belgium, Canada, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, the UK, Israel, Italy, Japan, Korean Republic, Netherlands, Norway, Poland, Sweden, Singapore and the USA. Our sample is mostly dominated by US deals, followed by those in Canada, Japan, France, the UK and Germany. Our sample of buyout deals terminates in 2011, because we require 6 years of post-buyout patent data in order to construct the patent citation measures.

We only include buyout deals where the target firm had at least one successful patent applied for and granted from the 3 years prior to the 3 years after the transaction (similarly to Lerner, Sorensen and Strömberg, 2011). Our final sample is comprised of 307 going-private deals involving 26,360 patents, of which 33% are conducted in cross-border deals where the target and acquirer are from different countries. Generally, 38% of acquirers are classified as very large (i.e. total assets greater than 260 million USD), 10% as large (i.e. total assets greater than 26 million USD), 10% as medium size (i.e. total assets greater than 2.6 million USD) and 42% as small.

6 Zephyr has been used in previous studies (e.g. Erel, Jang and Weisbach, 2015).

7 Merging PATSTAT data with that of other datasets requires fuzzy matching based on firms' names. This is an involved process that uses country-specific dictionaries of legal entity names, common names and phrases. String matching algorithms are then used to match firm names across different datasets.

Measuring innovation

Our primary goal is to measure innovation quantity and quality. We use a simple patent count to proxy for innovation quantity, and two other measures to evaluate quality and importance of innovation. The first is absolute citation count, which captures citations made within the 3-year period from the year of patent grant date to the 3 years afterward. We use this measure to mitigate the issue of truncation at the end of the sample. The second is relative citation count. This measure calculates citations received for patents filed and subsequently granted during the year of the patent grant through the 3 years afterwards, less the average number of citations during the period received by the matching patents. We follow Lerner, Sorensen and Strömberg (2011) and define matching patents as those granted in the same year and assigned to the same technology class.[8]

Because absolute and relative citation measures require 3 years of forward patent data, and because our study requires citation measures for 3 years from the date of the buyout, we require a total of 6 years of patent data from the date of the buyout. This limits us to considering buyout transactions up to 2011.

Control variables

Many factors drive innovative activity at the country and firm level. Following previous literature, we control for these characteristics. In particular, we include the intellectual property protection index created by Park (2008) and the level of a country's innovativeness as measured by patent applications scaled by GDP.

Hsu, Tian and Xu (2014) and Nanda and Rhodes-Kropf (2013) show that financial market development affects innovative activity. Thus, we include equity development measures as proxied for by the value of shares traded and scaled by GDP, and two credit market development measures. CMD1 is domestic credit to the private sector. This is an important indicator of the ability to finance production, consumption and capital formation, which in turn affects economic activity. CMD2 is domestic credit provided by the financial sector scaled by GDP, which measures banking sector depth and financial sector development in terms of size. We also include the GDP growth of a country to proxy for general economic conditions. We provide definitions for all variables and data sources in Table AI of the online Supporting Information.

Sample characteristics

Table 1 gives the summary statistics. Panel A presents the yearly distribution. The number of patents increased significantly from the year 2000. Similar to Lerner, Sorensen and Strömberg (2011), we attribute this to the increasing volume and growing share of technology firms, which typically innovate to a greater extent. There was another sharp increase in the number of public-to-private buyout transactions after 2005, primarily due to the cheap access to credit that was the main source of financing for LBOs. Subsequently, in 2008, the number of deals plummeted, to a level not seen since the late 1990s. This was attributable to the financial crisis, which caused a total standstill in deals, although that number began to rise again soon afterwards.

In Panel B, we show the distribution of transactions by industry. Similar to previous studies (e.g. Lerner, Sorensen and Strömberg, 2011), we find that manufacturing industries dominate in our sample.

Innovation change analysis

Summary statistics

Table 2 presents the descriptive statistics for the buyout sample (treated sample) and the control sample (discussed in the 'Research design' section). Our country-level controls for the buyout sample, such as the measure of intellectual property rights (IPR), have a mean of 7.97. The country innovativeness intensity (INV) measure implies that there are 1.66 patent applications submitted per 100 million of GDP, measured in US dollars. Equity market development (EMD) has a mean value of 172.87. Mean credit market development, measured as private credit to GDP (CMD1), is 166.70, and it is 200.17 when measured as domestic credit provided by the financial sector to GDP (CDM2). Average GDP growth is 2.15. Country-level controls for the control sample are fairly similar.

We present several firm characteristics 1 year before the buyout transaction. The buyout sample

[8]In order to identify the technology class, we use the PATSTAT - IPC classification.

Table 1. Sample distribution: This table presents the sample construction and the target industry (Panel B) for deals announced from 1997 to 2011 with at least one patent granted to the target firm for the 3 years before to the 3 years after the transaction

Panel A: Distribution by year

Year	Deals #	Patents #	Deals # with radical patents	Radical patent #
1997	1	9	–	–
1998	2	104	–	–
1999	14	186	3	7
2000	16	2,431	10	93
2001	13	830	9	53
2002	14	410	3	16
2003	35	4,314	16	591
2004	19	725	11	25
2005	34	2,455	17	106
2006	30	3,967	15	1,024
2007	58	7,149	31	761
2008	19	520	9	47
2009	13	909	10	107
2010	14	243	11	73
2011	25	2,108	13	191
Total	**307**	**26,360**	**158**	**3,094**

Panel B: Distribution by industry

Industry	Deals #	Patents #	Deals # with radical patents	Radical patents #
Agriculture	2	92	2	6
Construction	1	1	–	–
Finance, Insurance	2	954	2	192
Manufacturing	187	23,888	94	2,608
Mining	3	12	1	1
Retail Trade	13	171	5	25
Services	80	1,108	44	237
Transportation	14	110	9	24
Wholesale Trade	5	24	1	1
Total	**307**	**26,360**	**158**	**3,094**

has total assets (ASSETS) of 1,098 on average, while the control firms have sales (SALES) at a level of 757. The research and development expenditures (R&D) are on average 44.58, capital expenditures (CAPEX) are 50.87 and free cash flow (FCF) is 81.56. The differences, although small, indicate that the control firms have more assets, higher sales, spend more on research and development, and have higher capital expenditures and less free cash flow. Yet these differences are not statistically significant, except for SALES and CAPEX.

Subsequently, we compare both samples of treated and control observations in terms of their innovation. The firms targeted in the buyout transactions have an average of 11.39 patents. The relative and absolute citations are 10.60 and 5.35, respectively. Figure 1 presents the trends in patents (A), absolute citations (B) and relative citations (C). The sample of buyouts has a higher level of innovation, yet the two samples show very distinct trends over time. For example, in Panel A, we observe an increase in the number of patents in the years before the buyouts; from year 0, the time trends for both subsamples differ. The number of patents for the buyout sample begins to drop, but the number of patents for the control sample increases steadily over time. The figures for citations show similar trends.

Baseline regressions

In the multivariate analysis, we use patent count and citations as dependent variables. Given that the patent count variable is highly skewed, we transform it into ln(1 + patent count) in the

Table 2. Summary statistics: This table presents the summary statistics for deals announced from 1997 to 2011

	Treatment		Control		
Variable	Mean	S.D.	Mean	S.D.	t-Statistic for the difference in means
IPR	7.97	0.49	8.00	0.48	1.64
INV	1.66	1.63	1.69	1.61	0.69
EMD	172.87	90.03	177.40	90.32	1.75
CMD1	166.70	41.41	168.57	40.52	1.55
CDM2	200.17	53.00	202.66	52.82	1.59
GDP_GR	2.15	1.75	2.15	1.72	−0.09
ASSETS	1,098	3,372	1,370	6,152	1.54
SALES	757	1,377	1,106	4,310	2.89
R&D	44.58	131.91	53.83	258.79	0.88
CAPEX	50.87	134.17	70.51	259.95	2.26
FCF	81.56	251.37	80.06	359.97	−0.14

regression analysis.[9] In column (1) of Table 3, we present the results of a 'before–after' analysis, where we include industry, firm and country–year fixed effects, and cluster standard errors by firm. We find a significant decline in the number of patent applications post-buyout transaction, ranging from 18% in year 2 to 22% in year 3.[10] This is also economically significant, translating into up to three less patents each year.

The innovation drop may be due to the fact that PE firms tend to buy certain firms. In this analysis, we match buyout firms to public firms by age, profitability, year and country in order to mitigate those concerns. Our empirical tests are based on DiD methods, where we compare change in innovation among firms that went through a public-to-private buyout (the treatment group) with change in innovation among a matched group of public firms that remained public (the control group).

In column (2) of Table 3, we present the results from the DiD methodology discussed earlier. The results show a similar pattern, with a 17% drop in the number of patents in year 2 and 22% in year 3 compared to public firms matched by year, size, three-digit industry code and age.

In columns (1) and (2) of Table 4, we present the results of 'before–after' analyses where the dependent variables are 'Absolute Citations' and 'Relative Citations', respectively. We include industry, firm and country–year fixed effects, and cluster the standard errors by firm. We find a significant decline in the number of citations post-buyout transaction, ranging from 32% to 41% in year 2, and from 36% to 46% in year 3.[11]

In column (2) of Table 4, we present the results from the DiD methodology. The results show a decline in the number of citations from 24% to 33% in year 2, and from 22% to 30% in year 3, compared to public firms matched by year, size, three-digit industry code and age. The 46% reduction in patent citations measured as absolute citations translates into up to five less citations each year compared to the mean number of absolute citations; the 36% reduction in patent citations measured as relative citations translates into up to two less citations each year compared to the mean number of relative citations.

Addressing endogeneity of the going-private decision

A decision to delist a public firm is not random, and therefore our analysis is subject to endogeneity. In the previous section, we attempted to mitigate this concern by performing a DiD analysis that matches on industry, size, age and year. In this subsection, we extend this analysis by employing two alternative matching methods. First, we construct a sample of matched firms that are similar in terms of going-private characteristics. In particular, following Bharath and Dittmar (2010), we identify several characteristics as future predictors

[9] In a previous version of this paper, we used the levels and applied count models. The results were similar to those reported here.

[10] The untabulated results are robust if we include country and firm characteristics. However, including them reduces the number of observations.

[11] The untabulated results are robust if we include country and firm characteristics, but including them significantly reduces the number of observations.

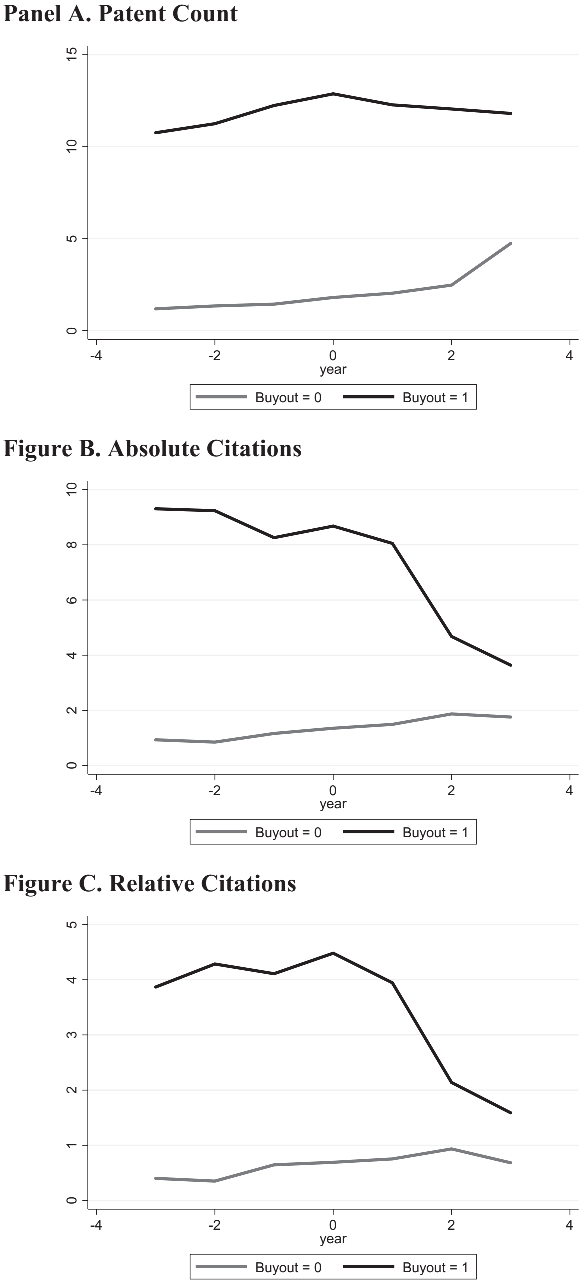

Figure 1. Innovation measures for treatment and control samples over time: (A) patent count; (B) absolute citations; (C) relative citations

of going private. We create a sample that is similar to the buyout sample in terms of total assets, sales, R&D, Capex, dividends, free cash flow, debt, cash and net fixed assets[12] measured at the time of IPO,

Table 3. Changes in innovation around the 'going-private' decision: BA and DID specifications (from both going-private and control samples)

	Before–after (1)		DiD (2)	
	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0009	[0.01]	0.0395	[0.56]
Event year −2	0.0904	[1.17]	0.1061*	[1.78]
Event year −1	−0.0039	[−0.06]	0.0404	[0.79]
Event year 1	−0.0862	[−1.52]	−0.0712	[−1.41]
Event year 2	−0.1751***	[−2.68]	−0.1739***	[−3.11]
Event year 3	−0.2194***	[−2.78]	−0.2228***	[−3.20]
Fixed effects	Industry, firm, country × year		Industry–size–age–year	
Obs.	1,505		8,603	

Columns (1) and (2) present OLS panel regressions for before–after analysis, with the dependent variable ln(1 + number of patents) in models (1) and (2). In model (1), we include industry, firm and country–year fixed effects. Standard errors are clustered by firm. Column (2) presents difference-in-differences regression results. For each firm in the going-private sample, we include up to five public firms (based on data availability) that are matched to the going-private firms by year, size, three-digit industry code and age. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1).
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

which is on average 13 years prior to going private. Similarly, as discussed previously, we include the 'cell' effects.

Second, in order to mitigate concerns that pre-buyout innovation may affect the results, we construct a sample of matched firms that are similar in terms of pre-innovation characteristics. This should resolve any concerns that we are analysing firms at different timelines in the innovation cycle. We present the results from these two alternative DiD analyses in Table 5. In columns (1) and (2), we present the DiD results when firms are matched on the going-private characteristics; in columns (3) and (4), we present the results matched on 3-year pre-innovation (measured by the number of patents and citations in years 1 to 3), industry, size, age and year characteristics. The results also show a negative effect of going private on innovation. The coefficients suggest a decline in the number of citations, from 27% to 34% in year 2, and from 15% to 25% in year 3.

Third, we verify whether the results are robust to a different matching technique. We match treated and control observations based on the

[12]There are many missing values for those variables. Where possible, we replace them with industry-year averages.

Table 4. Changes in innovation around the 'going-private' decision: BA and DID specifications (from both going-private and control samples)

	Before–after				DiD			
	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0358	[0.21]	−0.0401	[−0.26]	0.1013	[0.96]	0.0565	[0.62]
Event year −2	−0.0174	[−0.12]	−0.0503	[−0.39]	0.1029	[1.17]	0.0995	[1.26]
Event year −1	−0.0779	[−0.60]	−0.0734	[−0.63]	−0.0021	[−0.03]	−0.0011	[−0.02]
Event year 1	−0.1162	[−0.79]	−0.1127	[−0.89]	−0.0878	[−1.00]	−0.0749	[−1.02]
Event year 2	−0.4070***	[−2.94]	−0.3176***	[−2.67]	−0.3284***	[−3.86]	−0.2449***	[−3.35]
Event year 3	−0.4554***	[−3.41]	−0.3632***	[−2.91]	−0.3030***	[−3.34]	−0.2162***	[−2.74]
Fixed effects	Industry, firm, country × year				Industry–size–age–year			
Obs.	1,505		1,505		8,603		8,603	

Columns (1) and (2) present OLS panel regressions for before–after analysis, with the dependent variables ln(1 + absolute citations) in model (1) and ln(1 + relative citations) in model (2). In models (1) and (2), we include industry, firm and country–year fixed effects. Standard errors are clustered by firm. Columns (3) and (4) present difference-in-differences regression results, with the dependent variables ln(1 + absolute citations) in model (3) and ln(1 + relative citations) in model (4). For each firm in the going-private sample, we include up to five public firms (based on data availability) that are matched to the going-private firms by year, size, three-digit industry code and age. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1).
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

Table 5. Changes in innovation around the 'going-private' decision: DID specifications (from both going-private and control samples)

	DiD							
	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.1679	[1.16]	0.0952	[0.72]	0.1491	[1.29]	0.1068	[1.08]
Event year −2	0.0896	[0.69]	0.0557	[0.48]	0.1441	[1.35]	0.1357	[1.44]
Event year −1	0.0104	[0.09]	−0.0214	[−0.19]	0.0125	[0.14]	0.0023	[0.03]
Event year 1	−0.1151	[−0.85]	−0.1020	[−0.86]	−0.1362	[−1.25]	−0.0953	[−1.02]
Event year 2	−0.3250**	[−2.37]	−0.2699**	[−2.26]	−0.3363***	[−3.06]	−0.2660***	[−2.83]
Event year 3	−0.2528**	[−2.10]	−0.1825*	[−1.68]	−0.2136*	[−1.82]	−0.1516	[−1.52]
Fixed effects	Going-private characteristics				Pre-innovation, industry–size–age–year			
Obs.	2,086				2,996			

Columns (1) to (4) present difference-in-differences regression results, with the dependent variables ln(1 + absolute citations) in models (1) and (3) and ln(1 + relative citations) in models (2) and (4). In columns (1) and (2) for each firm in the going-private sample, we include one public firm (based on data availability) that is matched to the going-private firms on variables that determine the propensity of going private measured for the prior 13 years: total assets, sales, R&D, Capex, dividends, free cash flow, debt, cash, net fixed assets (we replace any missing values with industry–year averages). In columns (3) and (4) for each firm in the going-private sample, we include one public firm (based on data availability) that is matched to the going-private firms on pre-innovation measures: year, size, three-digit industry code and age. Standard errors are clustered by firm. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1).
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

Mahalanobis distance measure on firm characteristics such as industry, size, age and year. The results are in Table 6. We continue to find a negative and statistically significant effect of public-to-private buyouts on innovation. The coefficients are also of similar magnitude (i.e. we observe a drop in the number of citations of 19% to 26% in year 2, and up to 27% in year 3).

Further analysis

Institutional and management buyouts

In this subsection, we distinguish between IBOs and MBOs, because we expect institutional investors to have different incentives and long-term objectives than insiders such as firm management. Theoretically, going private in a highly leveraged

Table 6. Changes in innovation around the 'going-private' decision: DID specifications (from both going-private and control samples)

	DiD			
	(1)		(2)	
	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0973	[0.86]	0.0620	[0.64]
Event year −2	0.1009	[1.07]	0.0986	[1.18]
Event year −1	0.0042	[0.05]	0.0058	[0.08]
Event year 1	−0.0880	[−0.94]	−0.0567	[−0.74]
Event year 2	−0.2612***	[−3.03]	−0.1886**	[−2.52]
Event year 3	−0.2739**	[−1.99]	−0.1950	[−1.59]
Fixed effects	Industry, firm, country × year		Industry, firm, country × year	
Obs.	3,303		3,303	

Columns (1) and (2) present difference-in-differences regression results, with dependent variables ln(1 + absolute citations) in model (1) and ln(1 + relative citations) in model (2). In columns (1) and (2) for each firm in the going-private sample, we include one public firm (based on data availability) matched to the going-private firms based on the Mahalanobis distance measure on firm characteristics such as industry, size, age and year. Standard errors are clustered by firm. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1).
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

IBO transaction does not relieve a target firm from short-term pressures. In fact, servicing a huge debt may preclude a firm from realizing long-term investment strategies. In contrast, in an MBO, the insiders may be focused on servicing debt as well as on long-term planning. They may have reputational and career concerns and, as a result, may desire to keep the firm in solid shape after returning it to the public sector.

Table AII of the online Supporting Information presents the summary statistics when we divide the buyout sample into IBOs and MBOs. MBOs have a slightly lower level of innovation measured in number of patents or citations, yet a higher level of radical innovation (measured as number of patents granted to firm i in year t that have at least one citation to non-patent literature). They also tend to take place in countries with higher investor protection and less developed equity markets.

Table 7 (Panel A) shows 'before–after' and DiD results for limiting the sample to IBOs only. We find a significant drop in both absolute and relative citations following IBOs. Panel B shows our results for limiting the sample to MBOs only. Within all models, we observe no statistically significant effect on absolute or relative citations post-buyout. These results indicate that the negative effect from buyouts is observed predominantly for IBOs, but not for MBOs.

Radical innovation

Thus far, we have analysed various general measures of innovation. However, the nature of innovation can differ. Certain patents, for example, may refer directly to scientific literature, and may be considered more radical than incremental in nature. Following Griffith and Macartney (2014), we thus define radical innovation as the total number of patents granted to firm i in year t that have at least one citation to non-patent literature (NPL). NPL generally refers to scientific journals, and therefore patents making citations to NPL are likely to be new and represent radical innovations. In order to identify the effect of buyouts on radical innovation, we limit our sample to target firms that had at least one radical patent applied for and granted within the period of 3 years before to 3 years after the buyout.

The results are in Table 8. We find that the number of radical innovations tends to drop after the buyout transaction. We observe a statistically and economically significant decrease in radical innovation 1, 2 and 3 years post-buyout.

Innovation efficiency or short-term payoffs?

In previous subsections, we demonstrated that innovation generally drops after going private. This may be due to PE firms restructuring R&D departments. We therefore look next at innovator employment changes. If PE firms are focused on long-term investment projects, we expect them to expand and keep the R&D units operational. Alternatively, if their focus is solely short term, we expect to observe employment reductions in innovator employment.

We create a novel measure of innovation efficiency, computed as the number of patent applications filed and subsequently granted during the year, divided by the number of unique innovators. We consider unique innovators as those listed on the patent application. If the same person is included in multiple applications, we count that person only once. This measure also considers how efficiently a firm uses its R&D team following a

Table 7. Institutional and management buyouts: Changes in innovation around the 'going-private' decision: BA and DID specifications (from both going-private and control samples)

Panel A: Institutional buyouts

	Before–after				DiD			
	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0388	[0.21]	−0.0467	[−0.29]	0.0912	[0.81]	0.0581	[0.59]
Event year −2	0.0033	[0.02]	−0.0310	[−0.23]	0.0994	[1.05]	0.1087	[1.29]
Event year −1	−0.0721	[−0.53]	−0.0708	[−0.57]	−0.0019	[−0.02]	0.0061	[0.09]
Event year 1	−0.1078	[−0.69]	−0.1110	[−0.83]	−0.0884	[−0.95]	−0.0778	[−0.99]
Event year 2	−0.4402***	[−3.00]	−0.3290***	[−2.59]	−0.3552***	[−3.93]	−0.2517***	[−3.24]
Event year 3	−0.4679***	[−3.26]	−0.3451***	[−2.61]	−0.3392***	[−3.51]	−0.2404***	[−2.86]
Fixed effects	Industry, firm, country × year				Industry−size−age−year			
Obs.	1,414		1,414		7,983		7,983	

Panel B: Management buyouts

	Before−after				DiD			
	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	−0.0022	[−0.01]	0.0415	[0.11]	0.1426	[0.87]	−0.0158	[−0.10]
Event year −2	−0.2758	[−0.68]	−0.2924	[−0.70]	0.1237	[1.05]	0.0005	[0.00]
Event year −1	−0.1505	[−0.32]	−0.1053	[−0.25]	−0.0236	[−0.11]	−0.1177	[−0.55]
Event year 1	−0.2213	[−0.54]	−0.1339	[−0.34]	−0.0851	[−0.48]	−0.0815	[−0.54]
Event year 2	0.0081	[0.02]	−0.1746	[−0.52]	−0.0846	[−0.45]	−0.1819	[−1.08]
Event year 3	−0.2981	[−1.00]	−0.5887	[−1.37]	0.0253	[0.14]	0.0052	[0.03]
Fixed effects	Industry, firm, country × year				Industry−size−age−year			
Obs.	168		168		798		798	

Columns (1) and (2) present OLS panel regressions for before–after analysis, with the dependent variables ln(1 + absolute citations) in model (1) and ln(1 + relative citations) in model (2). In models (1) and (2), we include industry, firm and country–year fixed effects. Standard errors are clustered by firm. Columns (3) and (4) present difference-in-differences regression results, with the dependent variables ln(1 + absolute citations) in model (3) and ln(1 + relative citations) in model (4). For each firm in the going-private sample, we include up to five public firms (based on data availability) that are matched to the going-private firms by year, size, three-digit industry code and age. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1).
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

buyout. Innovation efficiency can be improved by either increasing the number of patent applications while keeping the size of the R&D team constant, or producing the same number of patent applications using a smaller R&D team.

The results for innovation efficiency are in Table 9. Similar to the findings for patent counts, radical patent counts, absolute citations and relative citations, we find that buyouts have a significantly negative effect on innovation efficiency. The drop in innovation efficiency results from the fact that the rate of decrease in innovation is higher than the rate of decrease in the number of unique innovators.

Syndicate size

PE investors may form syndicates, which are a consortium of multiple investors that are financing the same portfolio firm. There are several reasons for this activity. There is some concern that such PE partnerships may be colluding to depress prices. For example, Officer, Ozbas and Sensoy (2010) find a 40% overall 'club deal discount'. However, Boone and Mulherin (2011) suggest other reasons for consortium formations, such as scale, risk and bidder expertise. Cumming (2006) suggests that syndication, through better screening and selection of investments, might reduce agency conflicts.

Table 8. Estimates of radical patent count

	(1)		(2)		(3)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0035	[0.08]	0.0036	[0.08]	0.0479	[0.64]
Event year −2	0.0318	[0.84]	0.0309	[0.78]	0.0574	[0.97]
Event year −1	−0.0051	[−0.16]	−0.0088	[−0.27]	0.0083	[0.17]
Event year 1	−0.0391	[−1.21]	−0.0479	[−1.44]	−0.0199	[−0.44]
Event year 2	−0.1071***	[−2.81]	−0.1108***	[−2.79]	−0.0936*	[−1.68]
Event year 3	−0.1564***	[−3.66]	−0.1664***	[−3.71]	−0.1491***	[−2.64]
Country controls	No		Yes		No	
Firm FE	No		No		Yes	
Country–year FE	No		No		Yes	
Obs.	1,456		1,407		1,456	

We present OLS panel regressions with the dependent variable ln(1 + radical count). In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1). Standard errors are clustered by firm.
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

Table 9. Estimates of innovation efficiency

	(1)		(2)		(3)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	−0.0008	[−0.02]	−0.0002	[−0.01]	−0.0388	[−0.74]
Event year −2	0.0172	[0.48]	0.0174	[0.49]	−0.0085	[−0.17]
Event year −1	0.0246	[0.81]	0.0133	[0.44]	−0.0263	[−0.68]
Event year 1	−0.0694**	[−2.07]	−0.0804**	[−2.35]	−0.1086**	[−2.31]
Event year 2	−0.0745**	[−2.22]	−0.0854**	[−2.53]	−0.1035**	[−2.15]
Event year 3	−0.0776**	[−2.05]	−0.0854**	[−2.20]	−0.0870	[−1.54]
Country controls	No		Yes		No	
Firm FE	No		No		Yes	
Country–year FE	No		No		Yes	
Obs.	1,456		1,407		1,456	

We present OLS panel regressions where the dependent variable innovation efficiency is winsorized at 1%. In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1). Standard errors are clustered by firm.
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

PE consortiums may also be formed to certify the deal quality of a highly levered transaction to debtholders (Officer, Ozbas and Sensoy, 2010). As these authors suggest, it may be relatively easier to obtain debt financing and on more favourable terms if there are multiple PE firms syndicating the deal. We therefore expect that deals involving a larger number of PE investors will obtain better financing terms that will put less pressure on their investment decisions. That could lead to less pressure to cut investments in innovation.

In order to test this hypothesis, we divide our sample into deals that have one or more PE investors. The results are in Table 10. We observe negative and statistically significant effects of public-to-private buyouts on innovation for deals with only one PE investor. The coefficients suggest a decline in the number of citations of 36% to 47% in year 2, and 39% to 52% in year 3. We find no statistically significant evidence of public-to-private buyout transactions on innovation for deals backed by a syndicate. This result supports the intuition that syndicates, which generally enjoy more favourable financing terms, try to avoid cuts in long-term investments.

Buyouts and the cost of debt

Now that we have shown that innovation drops after going private, the question is: Why do PE

Table 10. Estimates of citations: syndicate size

	Syndicate = 1				Syndicate > 1			
	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0196	[0.10]	−0.0149	[−0.09]	0.0969	[0.20]	−0.1362	[−0.34]
Event year −2	−0.0876	[−0.56]	−0.1101	[−0.76]	0.2543	[0.64]	0.1819	[0.58]
Event year −1	−0.0814	[−0.55]	−0.0779	[−0.57]	−0.0615	[−0.20]	−0.0533	[−0.21]
Event year 1	−0.2298	[−1.35]	−0.1991	[−1.30]	0.3264	[1.02]	0.2245	[0.89]
Event year 2	−0.4728***	[−3.00]	−0.3601***	[−2.65]	−0.1387	[−0.40]	−0.1422	[−0.47]
Event year 3	−0.5150***	[−2.95]	−0.3933**	[−2.50]	−0.2092	[−0.92]	−0.2341	[−0.93]
Country controls	No		No		No		No	
Firm FE	Yes		Yes		Yes		Yes	
Country–year FE	Yes		Yes		Yes		Yes	
Obs.	1,169		1,169		448		448	

This table presents regressions where the dependent variable citation count is measured by absolute citations in columns (1) and (3) and by relative citations in columns (2) and (4). In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1). Standard errors are clustered by firm.
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

firms pay for positive net present value (NPV) projects, and then abandon them? It would be illuminating to examine the underlying reasons for the post-buyout drop in innovation. Deep-pocketed investors may seem more likely to nurture innovation, because we expect them to better tolerate short-term failure. However, they seem to rely heavily on debt financing. The debt overhang theory of Myers (1977) posits that management of an excessively leveraged firm will forgo positive NPV projects if the new projects benefit debtholders rather than equity holders.

In general, the buyout transaction is not only related to the change in ownership, it also changes the target firm's capital structure and shifts it towards higher leverage. The buyouts are financed mostly with debt, so as much as 80% of the transaction cost may be debt financing. At the time of the buyout announcement, the acquirer and the lender have agreed upon the terms and payout structure. However, the debt portion may be a significant burden for the planned restructuring of the target firm during the buyout period. Moreover, financing may be received from multiple debt providers, which makes it more difficult to effect a refinancing (Axelson *et al.*, 2013; Colla, Ippolito and Wagner, 2012; Demiroglu and James, 2010; Graham and Leary, 2011; Kaplan and Stein, 1993).

Financing in these highly leveraged transactions is often defined as a fixed debt plan. The valuation is made based on the assumption that debt is expected to be a function of time alone, agreed at the time of the investment (Baldwin, 2001a, 2001b; Cooper and Nyborg, 2018). Most prior studies have analysed the effects of buyouts on investment and productivity in isolation, but these decisions are not typically separate. In this subsection, we analyse the effects together.

It is critical for an acquirer to negotiate the best debt terms for a buyout transaction. If an acquirer can *ex post* lock in deal financing for subsequent post-buyout years at a lower rate than that currently experienced by other market participants, it will have a critical investment advantage over the competition. Thus, the effect of the buyout on innovation should be positive. But the reverse also holds. If an acquirer *ex post* locks in deal financing at a higher rate than that of current market participants, it may have a negative effect on investment and innovation.

In order to control for the cost of debt, we include the relative ratio of the initial cost of debt at the time of announcement, and the cost of debt in the first, second and third years post-buyout, respectively, in the regression analysis. Data on the cost of debt come from Federal Reserve Economic Data, and we use the corporate debt yield at the time of announcement at the subgroup country level.

Our results are presented in Table 11. They show that the effect of the relative cost of debt after a

Table 11. Estimates of citations with the cost of debt

	(1)		(2)		(3)		(4)	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Event year −3	0.0294	[0.27]	0.0358	[0.21]	−0.0192	[−0.20]	−0.0401	[−0.26]
Event year −2	0.0111	[0.12]	−0.0174	[−0.12]	0.0142	[0.16]	−0.0503	[−0.39]
Event year −1	−0.0523	[−0.63]	−0.0779	[−0.60]	−0.0386	[−0.53]	−0.0734	[−0.62]
Event year 1	0.4005*	[1.67]	0.4945*	[1.68]	0.3216*	[1.81]	0.4089*	[1.82]
Event year 2	−0.1289	[−0.77]	−0.1960	[−1.00]	−0.1233	[−0.98]	−0.1612	[−1.06]
Event year 3	0.0563	[0.29]	0.0435	[0.19]	0.0722	[0.41]	0.0481	[0.21]
CD year 1	−0.4493**	[−2.19]	−0.5743**	[−2.37]	−0.3776**	[−2.52]	−0.4905***	[−2.62]
CD year 2	−0.1743	[−1.45]	−0.1903	[−1.43]	−0.1141	[−1.30]	−0.1410	[−1.32]
CD year 3	−0.3241**	[−2.21]	−0.3937***	[−2.61]	−0.2827**	[−2.27]	−0.3246**	[−2.29]
Country controls	Yes		No		Yes		No	
Firm FE	No		Yes		No		Yes	
Country–year FE	No		Yes		No		Yes	
Obs.	1,393		1,561		1,393		1,561	

This table presents regressions where the dependent variable citation count is measured by absolute citations in columns (1) and (2), and by relative citations in columns (3) and (4). In all models, we show the regression where the independent variables are the relative years pre- and post-buyout (event year 0 is the omitted base category, with a coefficient normalized to 1). Standard errors are clustered by firm.
All variables are defined in Table AI. ***, ** and * denote 1%, 5% and 10% significance levels, respectively.

buyout transaction negatively affects innovation. In particular, the CD (cost of debt) in year 1 after the buyout (i.e. the ratio of CD at the time of announcement to CD at the first year post-announcement) has a negative and significant effect on innovation. The CD in year 2 post-buyout (the ratio of CD at the time of announcement to that at the second year post-announcement) has a negative but not significant effect on innovation. The CD in year 3 post-buyout (the ratio of CD at the time of announcement to CD at the third year post-announcement) has a negative and significant effect on innovation. Overall, this means that the decrease in the post-buyout cost of debt, compared to the initial cost of debt at the time of announcement, has a negative effect on innovation.

Interestingly, the effect of the post-buyout years becomes positive in years 1 and 3, suggesting that it is dependent on the relative cost of debt at the year of announcement relative to the current cost of debt. We posit that, if an acquirer is able to lock in a lower cost of debt over the duration of the restructuring compared to the post-buyout cost of debt, the incentives to innovate will be stronger. However, if the current cost of debt is lower than the cost of debt at announcement, the investment in innovation will no longer be lucrative, and the incentives to innovate will decrease.

Robustness analysis and limitations

In subsequent untabulated tests, we analyse whether the results hold for different subsamples. We split our sample into public-to-private US and non-US buyouts. The negative results are stronger for the US subsample, but also hold for the non-US subsample. We also divide the data into pre- and post-2006 subsamples. Most previous studies report the results for pre-2006 data. We check whether a specific subperiod may be driving the negative results. We find that they are mostly insignificant for the pre-2006 subsample, and highly significant for the post-2006 subsample.

We also collect data for private-to-private buyouts, which is a much larger sample than for public-to-private buyouts. We find no significant evidence of any effect on innovation for the full sample of private-to-private buyouts. However, when we split the sample into pre- and post-2006 subsamples, we find a negative association in year 3 post private-to-private buyout for the post-2006 period.

PE funds also engage in secondary buyouts (SBOs). Research shows that, under pressure, PE funds engage in more SBOs that ultimately underperform (Arcot *et al.*, 2015). Secondary management buyouts (SMBOs) also tend to perform worse than regular MBOs (Jelic, Zhou and Wright, 2019; Zhou, Jelic and Wright, 2014). We evaluate the extent to which our results may be affected by these deals. Approximately 10% are SBOs. We exclude those transactions, and our estimates remain robust.

We are unable to disentangle the effects of board advisory and PE human capital on innovation. Thus, in order to mitigate any concerns about PE characteristics in our analysis, we run a model where we include PE firm fixed effects. The results remain robust.

We also explore whether our results are robust to alternative estimation methods, where we correct for serial correlation. We apply a linear dynamic panel data model that includes a lagged value of the dependent variable. The results are similar to our main results, and show a negative and statistically significant effect of buyouts on innovation in years 2 and 3, post-buyout.

We caution that our results may overestimate the negative effects of buyout transactions because we are only observing what happens in the post-buyout firm. It is possible that divisions or subsidiaries are sold to another firm, and patenting activity may continue there.

Moreover, our data are not rich enough to analyse several remaining research questions, so we leave them for future studies. For example, future work may explore the effect of PE firm reputation on innovation. Measures such as textual analysis could analyse patent documents and their disclosures. It could also be instructive to examine what happens post-buyout transaction to divisions and subsidiaries that are sold. We note that, in untabulated analyses, we find little evidence of a drop in innovation for a sample of private-to-private deals. Future research may focus on the determinants of those differences, and compare debt levels between public-to-private and private-to-private deals.

Conclusion

This paper explores the impact of public-to-private buyout transactions on the innovation of target firms. We analyse both quantity (patent count) and quality (citations) of patent activity. Following public-to-private buyouts, we find that firms tend to have fewer patents overall, and to receive fewer citations on those patents. Firms also have fewer radical (e.g. scientific) innovations. We observe that the negative effect of public-to-private buyouts is only significant for institutional buyouts. We identify a significant decrease in innovation efficiency post-going private. We also show that the negative effect is most prevalent for transactions where the cost of the debt financing is higher than the post-buyout cost of debt.

Our results add to prior literature, but they also contrast with those of Amess, Stiebale and Wright (2016) and Lerner, Sorensen and Strömberg (2011), who show innovation increases after buyout transactions. However, those results are driven mostly by private-to-private transactions. Our study contributes by showing contrasting results for public-to-private transactions. The evidence is based on a buyout sample and matched sample analysis.

References

Acharya, V. V., O. F. Gottschalg, M. Hahn and C. Kehoe (2012). ‘Corporate governance and value creation: evidence from private equity’, *Review of Financial Studies*, **26**, pp. 368–402.

Aghion, P. and J. Tirole (1994). ‘The management of innovation’, *Quarterly Journal of Economics*, **109**, pp. 1185–1209.

Aghion, P., J. Van Reenen and L. Zingales (2013). ‘Innovation and institutional ownership’, *American Economic Review*, **103**, pp. 277–304.

Ahlers, O., A. Hack, K. Madison, M. Wright and F. W. Kellermanns (2017). ‘Is it all about money? Affective commitment and the difference between family and non-family sellers in buyouts’, *British Journal of Management*, **28**, pp. 159–179.

Amess, K., J. Stiebale and M. Wright (2016). ‘The impact of private equity on firms’ patenting activity’, *European Economic Review*, **86**, pp. 147–160.

Arcot, S., Z. Fluck, J. M. Gaspar and U. Hege (2015). ‘Fund managers under pressure: rationale and determinants of secondary buyouts’, *Journal of Financial Economics*, **115**, pp. 102–135.

Atanassov, J., V. Nanda and A. Seru (2007). ‘Finance and innovation: the case of publicly traded firms’. In D. Cumming (ed.), *The Oxford Handbook of Entrepreneurial Finance*. New York: Oxford University Press.

Axelson, U., T. Jenkinson, P. Strömberg and M. S. Weisbach (2013). ‘Borrow cheap, buy high? The determinants of leverage and pricing in buyouts’, *Journal of Finance*, **68**, pp. 2223–2267.

Ayash, B. and M. Rastad (2017). ‘Private equity, jobs, and productivity: a comment’. Available online at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3050984 or http://doi.org/10.2139/ssrn.3050984.

Ayash, B. and H. Schütt (2016). ‘Does going private add value through operating improvements?’, *Journal of Corporate Finance*, **40**, pp. 192–215.

Baker, G. P. and K. H. Wruck (1989). ‘Organizational changes and value creation in leveraged buyouts: the case of the OM Scott & Sons Company’, *Journal of Financial Economics*, **25**, pp. 163–190.

Baldwin, C. (2001a). *Technical Note on LBO Valuation (A) (9-902-004)*. Boston, MA: Harvard Business School.

Baldwin, C. (2001b). *Technical Note on LBO Valuation (B) (9-902-005)*. Boston, MA: Harvard Business School.

Belenzon, S., T. Berkovitz and P. Bolton (2009). 'Intracompany governance and innovation'. NBER Working Paper No. 15304.

Bergström, C., M. Grubb and S. Jonsson (2007). 'The operating impact of buyouts in Sweden: a study of value creation', *Journal of Private Equity*, **11**, pp. 22–39.

Bernstein, S. (2015). 'Does going public affect innovation?', *Journal of Finance*, **70**, pp. 1365–1403.

Bharath, S. and A. Dittmar (2010). 'Why do firms use private equity to opt out of public markets?', *Review of Financial Studies*, **23**, pp. 1771–1818.

Bharath, S., A. Dittmar and J. Sivadasan (2014). 'Do going-private transactions affect plant efficiency and investment?', *Review of Financial Studies*, **27**, pp. 1929–1976.

Boone, A. L. and J. H. Mulherin (2011). 'Do private equity consortiums facilitate collusion in takeover bidding?', *Journal of Corporate Finance*, **17**, pp. 475–1495.

Boot, A. W. A. and V. N. Vladimirov (2018). 'Collusion with public and private ownership and innovation'. Available online at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=30575556 or http://doi.org/10.2139/ssrn.3057555.

Boucly, Q., D. Sraer and D. Thesmar (2011). 'Growth LBOs', *Journal of Financial Economics*, **102**, pp. 432–453.

Burkart, M., D. Gromb and F. Panunzi (1997). 'Large shareholders, monitoring, and the value of the firm', *Quarterly Journal of Economics*, **112**, pp. 693–728.

Bushee, B. J. (1998). 'The influence of institutional investors in myopic R&D investment behavior', *Accounting Review*, **73**, p. 305.

Bushee, B. J. (2001). 'Do institutional investors prefer near-term earnings over long-run value?', *Contemporary Accounting Research*, **18**, p. 207.

Cohn, J. B., L. F. Mills and E. M. Towery (2014). 'The evolution of capital structure and operating performance after leveraged buyouts: evidence from US corporate tax returns', *Journal of Financial Economics*, **111**, pp. 469–494.

Colla, P., F. Ippolito and H. F. Wagner (2012). 'Leverage and pricing of debt in LBOs', *Journal of Corporate Finance*, **18**, pp. 124–137.

Cooper, I. A. and K. G. Nyborg (2018). 'Consistent valuation of project finance and LBOs using the flows-to-equity method', *European Financial Management*, **24**, pp. 34–52.

Cornelli, F. and O. Karakaş (2015). 'CEO turnover in LBOs: the role of boards'. Available online at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2269124 or http://doi.org/10.2139/ssrn.2269124

Cumming, D. (2006). 'Adverse selection and capital structure: evidence from venture capital', *Entrepreneurship: Theory & Practice*, **30**, pp. 155–183.

Davis, S. J., J. Haltiwanger, K. Handley, R. Jarmin, J. Lerner and J. Miranda (2014). 'Private equity, jobs, and productivity', *American Economic Review*, **104**, pp. 3956–3990.

Demiroglu, C. and C. M. James (2010). 'The role of private equity group reputation in LBO financing', *Journal of Financial Economics*, **96**, pp. 306–330.

Erel, I., Y. Jang and M. S. Weisbach (2015). 'Do acquisitions relieve target firms' financial constraints?', *Journal of Finance*, **70**, pp. 289–328.

Ferreira, D., G. Manso and A. C. Silva (2012). 'Incentives to innovate and the decision to go public or private', *Review of Financial Studies*, **27**, pp. 256–300.

Gillan, S. L. and L. T. Starks (2000). 'Corporate governance proposals and shareholder activism: the role of institutional investors', *Journal of Financial Economics*, **57**, pp. 275–305.

Goergen, M., N. O'Sullivan and G. Wood (2014a). 'The employment consequences of private equity acquisitions: the case of institutional buy outs', *European Economic Review*, **71**, pp. 67–79.

Goergen, M., N. O'Sullivan and G. Wood (2014b). 'The consequences of private equity acquisitions for employees: new evidence on the impact on wages, employment and productivity', *Human Resource Management Journal*, **24**, pp. 145–158.

Graham, J. R. and M. T. Leary (2011). 'A review of empirical capital structure research and directions for the future', *Annual Review of Financial Economics*, **3**, pp. 309–345.

Graham, J. R., C. R. Harvey and S. Rajgopal (2005). 'The economic implications of corporate financial reporting', *Journal of Accounting and Economics*, **40**, pp. 3–73.

Griffith, R. and G. Macartney (2014). 'Employment protection legislation, multinational firms, and innovation', *Review of Economics and Statistics*, **96**, pp. 135–150.

Guery, L., A. Stevenot, G. T. Wood and C. Brewster (2017). 'The impact of private equity on employment: the consequences of fund country of origin—new evidence from France', *Industrial Relations: A Journal of Economy and Society*, **56**, pp. 723–750.

Guo, S., E. Hotchkiss and W. Song (2011). 'Do buyouts (still) create value?', *Journal of Finance*, **66**, pp. 479–517.

Harford, J. and A. Kolasinski (2013). 'Do private equity returns result from wealth transfers and short-termism? Evidence from a comprehensive sample of large buyouts', *Management Science*, **60**, pp. 888–902.

Hsu, P.-H., X. Tian and Y. Xu (2014). 'Financial development and innovation: cross-country evidence', *Journal of Financial Economics*, **112**, pp. 116–135.

Jelic, R., D. Zhou and M. Wright (2019). 'Sustaining the buyout governance model: inside secondary management buyout boards', *British Journal of Management*, **30**, pp. 30–52.

Jensen, M. C. (1989). 'The eclipse of the public corporation', *Harvard Business Review*, **5**, pp. 61–74.

Kahn, C. and A. Winton (1998). 'Ownership structure, speculation, and shareholder intervention', *Journal of Finance*, **53**, pp. 99–129.

Kamoto, S. (2017). 'Managerial innovation incentives, management buyouts, and shareholders' intolerance of failure', *Journal of Corporate Finance*, **42**, pp. 55–74.

Kaplan, S. (1989). 'The effects of management buyouts on operating performance and value', *Journal of Financial Economics*, **24**, pp. 217–254.

Kaplan, S. N. (1991). 'The staying power of leveraged buyouts', *Journal of Financial Economics*, **29**, pp. 287–313.

Kaplan, S. N. and J. Stein (1993). 'The evolution of buyout pricing and financial structure in the 1980s', *Quarterly Journal of Economics*, **108**, pp. 313–357.

Lerner, J., M. Sorensen and P. Strömberg (2011). 'Private equity and long-run investment: the case of innovation', *Journal of Finance*, **66**, pp. 445–477.

Leslie, P. and P. Oyer (2008). 'Managerial incentives and value creation: evidence from private equity'. NBER Working Paper No. w14331.

Lichtenberg, F. R. and D. S. Siegel (1990). 'The effect of leveraged buyouts on productivity and related aspects of firm behavior', *Journal of Financial Economics*, **27**, pp. 165–194.
Manso, G. (2011). 'Motivating innovation', *Journal of Finance*, **66**, pp. 1823–1860.
Meckling, W. H. and M. C. Jensen (1976). 'Theory of the firm: Managerial behavior, agency costs and ownership structure', *Journal of Financial Economics*, **3**(4), pp. 305–360.
Moshirian, F., X. Tian, B. Zhang and W. Zhang (2019). 'Stock market liberalization and innovation', *Journal of Financial Economics*, Forthcoming.
Myers, S. (1977). 'Determinants of corporate borrowing', *Journal of Financial Economics*, **5**, pp. 147–175.
Nanda, R. and M. Rhodes-Kropf (2013). 'Investment cycles and startup innovation', *Journal of Financial Economics*, **110**, pp. 403–418.
Officer, M. S., O. Ozbas and B. A. Sensoy (2010). 'Club deals in leveraged buyouts', *Journal of Financial Economics*, **98**, pp. 214–240.
Park, W. (2008). 'International patent protection, 1960–2005', *Research Policy*, **37**, pp. 761–766.
Rappaport, A. (1990). 'The staying power of the public corporation', *Harvard Business Review*, **68**, pp. 96–104.
Renneboog, L. and C. Vansteenkiste (2018). 'The routledge companion to management buyouts'. In M. Wright, D. Siegel, K. Amess and N. Bacon (eds), *The Routledge Companion to Management Buyouts*, 1st edn, pp. 99–146. Abingdon: Routledge.
Shleifer, A. and R. W. Vishny (1986). 'Large shareholders and corporate control', *Journal of Political Economy*, **94**, pp. 461–488.
Smart, S. B. and J. Waldfogel (1994). 'Measuring the effect of restructuring on corporate performance: the case of management buyouts', *Review of Economics and Statistics*, **76**, pp. 503–511.
Smith, A. J. (1990). 'Corporate ownership structure and performance: the case of management buyouts', *Journal of Financial Economics*, **27**, pp. 143–164.
Stein, J. C. (1988). 'Takeover threats and managerial myopia', *Journal of Political Economy*, **96**, pp. 61–80.
Thompson, S. and M. Wright (1995). 'Corporate governance: the role of restructuring transactions', *The Economic Journal*, **105**, pp. 690–703.
Ughetto, E. (2010). 'Assessing the contribution to innovation of private equity investors: a study on European buyouts', *Research Policy*, **39**, pp. 126–140.
Weir, C., P. Jones and M. Wright (2015). 'Public to private transactions, private equity and financial health in the UK: an empirical analysis of the impact of going private', *Journal of Management & Governance*, **19**, pp. 91–112.
Zhou, D., R. Jelic and M. Wright (2014). 'SMBOs: buying time or improving performance?', *Managerial and Decision Economics*, **35**, pp. 88–102.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table AI. Variable definitions
Table AII. Summary statistics for the control sample. This table presents the summary statistics for deals announced from 1997 to 2011