Research and/or Development? Financial Frictions and Innovation Investment

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Abstract

U.S. firms have reduced their investment in scientific research ("R") compared to product development ("D"), raising questions about the returns to each type of investment, and about the reasons for this shift. We use Census data that disaggregates "R" from "D" to study how US firms adjust their innovation investments in response to an external increase in funding cost. Companies with greater demand for refinancing during the 2008 financial crisis, made larger cuts to R&D investment. This reduction in R&D is achieved almost entirely by reducing investment in research. Development remains essentially unchanged. If other firms patenting similar technologies must refinance, however, then Development investment declines. We interpret the latter result as evidence of technological competition: firms are reluctant to cut Development expenditures when that could place them at a disadvantage compared to potential rivals.

Keywords: Research and Development, Financial Crisis, Technology Competition.
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1 Introduction

The National Science Foundation (NSF) estimates that businesses were responsible for 74% of total U.S. investment in Research and Development (R&D) in 2019.[1] While this amount has grown in recent years, several scholars have voiced concerns about the composition of private R&D spending (Arora et al., 2018, Akcigit et al., 2021). In particular, there is increasing evidence that firms have reduced their investment in scientific research relative to later stages of the technology commercialization process. In simple terms, U.S. firms seem to doing less "R'" for each dollar of "D."

Most of the evidence that firms are shifting the composition of their R&D investments comes from either aggregate statistics or studies that use corporate publishing activity as a proxy for the output of basic research investments. In this paper, we use firm-level Census data on basic research, applied research, and development to study how each type of investment responds to an increase in the cost of capital. Specifically, we compare R&D investment by public firms with varying levels of exposure to short-term debt around the time of the 2008 financial crisis. Firms that entered 2008 with more extensive refinancing needs reduced R&D spending by a larger amount. The decline in R&D investment is explained almost entirely by a reduction in research – both basic and applied – as opposed to development. We also show that cuts to research were largely achieved through a contraction of labor costs and were not compensated by an increase in investment during the following year.

After establishing that firms were more likely to cut basic and applied research spending in response to financial pressures, we consider whether technological competition helps explain why development investments are "stickier." In particular, we show that whereas research investment is sensitive to a firm's own refinancing needs, development investment declines when other firms in the same industry are exposed to a large increase in the cost of refinancing. We interpret this finding as evidence that development investments are influenced by technological competition, and specifically a desire to keep up with rivals. Altogether, our findings show that periods of crisis may affect the trajectory of innovation of an economy by altering both the amount of resources

[1] The amount spent was estimated at $493 billion. See links: https://ncses.nsf.gov/pubs/nsf22303#:~:text=In%202019%2C%20of%20the%20%24493,billion%20(78%25)%20on%20development and https://ncses.nsf.gov/pubs/nsf22330.

committed to R&D as well as the types of projects that are undertaken. Furthermore, we also highlight the importance of the strategic interactions to determine the investment allocation.

In most empirical applications, our ability to study different types of R&D investment is constrained by a lack of data. In particular, though public companies often disclose aggregate R&D expenditures, there is no systematic reporting of how that spending is allocated across different categories. This study uses novel data set from two surveys conducted by the Census and the NSF: the Survey of Industry Research and Development (SIRD) for the period between 2005-2007; and the Business R&D and Innovation Survey (BRDIS) for 2008-2010. By combining these data sources, we are able to construct a panel data set of R&D activity at US firms that includes detailed information on different types of investments. We match this data to Compustat in order to obtain detailed financial information about each firm, which yields a sample of about 1,100 firms that covers a very significant share of total reported US R&D activity.

A particularly important dimension of our data is our ability to decompose total R&D across development and research. The allocation of innovative efforts across these two areas is crucial to assess how R&D investments will translate into new ideas or products and then affect the real economy (e.g., Akcigit et al. 2021; Griliches 1988; Link et al. 1981; Mansfield 1980, 1981). The key difference between research and development rests on whether the activity is aimed at creating new knowledge or simply leverage on existing knowledge and experience to introduce a new product or process. In particular, development - which in 2007 represented about 74.4% of total performed R&D - is defined by the NSF as the "systematic use of research and practical experience to produce new and significantly improved goods, services, or process." Research projects are instead identified activities that focus on a "planned, systematic pursuit of new knowledge or understanding," which could either have immediate commercial applications (i.e., applied research) or not (i.e., basic research).

Within this setting, the key objective of this paper is to understand how large, US firms adjust their key inputs in the innovation process when external market conditions make investing in R&D more difficult. Examining this question empirically is important also because theory is unable to provide an unambiguous characterization of what we should expect, in particular when comparing research and development. In normal times, we may expect companies to be more prone to cut research, since investments in this area are less likely to have an immediate impact on a the bottom line of the business. However, the opposite could also be true during a contractionary period, like in our context. During bad times, a firm may face weaker incentives to invest in activities with a short-term impact, like development, and companies may prefer focusing on explorative work (e.g., Manso et al., 2019), as research.

Furthermore, as we discuss in Section 3, the strength of these mechanisms also depends on the strategic interaction between firms (Benoit, 1984; Bolton and Scharfstein, 1990; Fudenberg and Tirole, 1986; Opler and Titman, 1994). For instance, while cutting development may be less of a problem when the economy is contracting, its impact also depends on whether other firms are doing the same things. If we consider a model where a firm's main motivation to invest is to keep up with competitors (e.g., Harris and Vickers, 1987), its decision to cut investment in a bad economic environment depends on its expectation about what other companies will do. As a result, a company experiencing an idiosyncratic shock may prefer to avoid cutting investments, since it anticipates the inability to coordinate towards lower investments. This mechanism should temper the overall response to the shock, but it may also influence a firm's decision about whether to cut between research or development. In particular, we should expect that strategic concerns should be more important for development, since this activity is more likely to be affected by competitive pressure.

To examine these issues, we study how differences across firms in refinancing needs at the onset of the 2008 financial crisis influenced their R&D investment. In particular, our main treatment variable measures the amount of debt due within one year as of 2007 relative to the amount of cash that the company had at the same time. The idea is that companies that are forced to access financial markets when funding options are scarce and more expensive (Santos, 2011) are more likely to scale back operations to relax the cash needs. Consistent with papers using a similar methodology (e.g., Almeida et al. 2009; Benmelech et al. 2019; Costello 2020; Granja and Moreira 2022), the basic identification assumption here is that refinancing needs are orthogonal to investment opportunities faced by companies during the crisis period. We believe that this assumption fits well the nature of the 2008 crisis: given the sharp and unexpected shift in financial conditions during that year, it is unlikely that firms' ex-ante balance sheet needs were simply and correctly reflecting a company's expectation about the crisis. Indeed, several other results are also consistent with the validity of our empirical framework. However, relative to the past literature, our ability to observe in the data firm-specific R&D projections allow to relax this assumption further. In fact, our data allows us to measure how much R&D a company was expecting to conduct in 2008 as of the end of 2007. Using this information, we can effectively net out from our estimate any potential correlation between a firm's balance sheet strength and R&D expectations.[2]

Using this empirical framework, we start by showing that companies with higher level of refinancing needs in 2008 cut R&D performed more extensively during that year. This result is estimated including in our model a narrow set of industry fixed-effects, and remains qualitatively identical when we augment the specification with firm-level controls. Importantly, controlling for firm-level expectations on R&D performed by the company also does not change the results, therefore providing further validation for our empirical approach. The estimated effect is sizable: an increase in debt due to liquid assets by 0.5 leads to 8% lower level of R&D growth between 2007 and 2008. This evidence confirms that the financing of innovative investments is indeed very sensitive to changes in financial conditions (Hall and Lerner, 2010; Kerr and Nanda, 2015).

Two results confirm that this reduction in R&D significantly impacted the production function of innovation for affected firms. First, we find that the cut in 2008 was not compensated by higher investment in the following year. While affected firms did not continue cutting R&D after 2008, the level adjustment made at the onset of the financial crisis persisted. Second, we find that a significant part of the cut in R&D was achieved by reducing labor costs. While we find some response across other cost categories, the reduction in labor cost accounts for about two third of the overall reduction in R&D. Given the large adjustment costs related to changing the labor force, this result may help explaining why this temporary shock persisted for a period.

We then examine how the type of R&D activity shifted in response to the shock. To study this question, we use our baseline analysis but now we focus on the growth of research and development activity separately. We find that the adjustment in R&D is

[2]Among the other things, this data also allows us to further validate the idea that the 2008 financial shock was not expected by the firms in the sample. In particular, we show that during the pre-crisis period companies' projections were indeed in line with what they ended up investing ex-post. However, this is not true in 2008, where projections ended up being about 15% higher than the actual R&D performed ex-post.

achieved almost entirely by cutting research, while development investments are largely unaffected. We also document that this reduction in research reflects cuts at both applied and basic research. This result suggests that the shock - on top of reducing the overall R&D investment - also significantly affected the way resources were allocated across areas.

As a last step, we try to shed some light on the mechanism that could explain this behavior. To start, we note that the heterogeneity between research and development is unlikely to simply reflect the difference in the duration of the two investments. If firms were cutting research because this action is less likely to affect their revenue in the short-run, we should find a similar difference when comparing basic and applied research. In fact, basic research – lacking ex-ante direct commercial applications — is the investment that has the lowest likelihood to have an impact on revenue in the foreseeable future. However, we find similar results across both applied and basic research; if anything the effect is slightly larger for applied. As we discuss in the paper, a similar logic also suggests that risk-based explanations are unlikely to play a leading role in our analysis (i.e., Krieger et al., 2022). Altogether, while these mechanisms may be at play in some way, they are unlikely to fully explain our findings alone.

An alternative hypothesis is that these results may reflect some of the strategic concerns discussed earlier. In particular, in light of the result found, it is possible that companies did not cut development investment because they were concerned that this action would put them at a significant disadvantage relative to their technology peers. To examine this hypothesis, we test whether a company's investments - on top of being affected by its own financial situation - were influenced by the financial conditions of technology peers. We use patent data to measure the degree of technology proximity of companies in our sample, as in Bloom et al. (2013), and then construct for each firm in our sample the average refinancing need in 2008 for those companies that are technologically close. We then replicate our previous analysis including both the firm's own measure of exposure to the financial crisis as well as the new measure of exposure for the technology peers.

Using this approach, we first show that total R&D declines relatively more when technology peers also experience a negative financial shock. This evidence is consistent with the idea that strategic interactions are important, and companies are more comfortable adjusting investments when firms operating in the same area are exposed to a similar shock. We then show that this effect is entirely driven by development. While companies tend to adjust research rather than development when their own financial conditions worsen, the opposite is true when we focus on the financial conditions of technologically close firms. In particular, companies cut more extensively development when their peers are on average also exposed to the need of refinancing in 2008, but research is largely unaffected by this measure. As we discussed above, this evidence is consistent with the importance of strategic interactions between firms in determining both the size and the quality of the adjustment.[3]

This paper contributes to several areas in economics. To start, this paper tries to shed new light on the determinants of innovative activity. While a large body of work has focused on how various economic forces influence the output of the innovation process (mostly focusing on patenting),[4] we have a much more limited understanding of how inputs are selected. As we discussed earlier, data availability likely explains the more limited number of studies focusing on this dimension. This distinction between input versus output is important for at least two reasons. First, if we are interested in understanding how changes in the economic environment will affect firms' incentives, studying the ex-post output will examine this question only indirectly. Second, innovation output is measured largely using patent data. Despite the importance of this data in the field, we also need to recognize that the use of patent data may be less than ideal in some contexts (Lerner and Seru, 2017). Indeed, patenting propensity across firms is driven by a lot of factors that may be unrelated to the actual underlying innovation (Mezzanotti et al., 2022). As a result, the use of patent data may not correctly capture the underlying change in investment, in particular when studying the response to relatively short-lived shocks, like in our case.

Thanks to Morris and Shin 2001, 2002; Angeletos and Pavan 2004 data, we can overcome some of the limitations of the previous literature and make two contributions. First, we show that negative shocks to the firm may affect both the level of R&D

[3]To be clear, this evidence does not imply that strategic forces are the only determinants of our results. Instead, our argument and results simply imply that this mechanism is likely playing an important role, but it possibly coexists with other explanations.

[4]Just to cite a few, the previous literature has provided some evidence on how innovation output is affected by government investments in R&D (e.g., Gross and Sampat, 2020; Moretti et al., 2019), laws on intellectual property (e.g., Moser, 2005; Mezzanotti, 2020; Mezzanotti and Simcoe, 2019), competition (e.g., Aghion et al., 2005), and exposure to innovation (e.g., Bell et al., 2019), taxation (e.g., Akcigit et al. 2017), among other things.

investments and their direction. In particular, our results highlight how companies may be more prone to cut research than development, when experiencing a negative financial shock.[5] This evidence is consistent with recent work by Babina et al. (2020b), which shows that the corporations' funding pushes university researchers to focus on more applied and less impactful work. Given the time lag between when research is conducted and when it impacts productivity in the economy (Syverson, 2011), this result suggests that the short-term cost of a crisis could underestimate its total impact. Furthermore, our results also show that labor adjustments are very important to explain changes in the R&D activity.

Our second core contribution is to highlight the importance of the strategic interactions between companies in order to determine firms' investments in equilibrium. In general, companies try to exploit the financial weakness of their peers, for instance by cutting prices or increasing investments (e.g. Campello, 2006; Chevalier, 1995; Cookson, 2017; Fresard, 2010; Grieser and Liu, 2019; Phillips, 1995). Our results suggest that companies may anticipate this response, and therefore ex-ante avoid adjustments in those areas where the strategic response by peers may be stronger. Our evidence suggests that this mechanism may play a role in explaining why investments in development are more resilient to a worsening in financial conditions.[6] More broadly, our analysis is consistent with recent theoretical work by Doraszelski et al. (2022), that shows how financial constraint does not necessarily induce lower investment because of the importance of strategic interactions.

Broadly, our paper also relates to the literature in finance focused on the connection between financial frictions and the real economy (e.g., Fazzari et al., 1988). Close to our setting, several papers have shown that the disruption of credit markets can significantly impair firms' tangible investment and employment decisions (e.g., Peek and Rosengren, 1997; Almeida et al., 2009; Schnabl, 2012; Lin and Paravisini, 2013; Chodorow-Reich, 2014; Frydman et al., 2015; Cingano et al., 2016; Bottero et al., 2020). However, much less work has focused on the causal impact of this type of financial shocks on R&D investment by

[5]This result is also consistent with the descriptive evidence in Driver et al. (2020) showing that companies with less financing issues (i.e., public companies) tend to invest relatively more in research relative to development.

[6]Our evidence is qualitatively consistent with what the predictions of investment models with externalities (e.g.,

large corporations.[7] Consistent with the framework in Hall and Lerner (2010), our results confirm that indeed R&D activity is very sensitive to changes in financial conditions. In this area, the papers closer to us are Brown et al. (2009) and Krieger et al. (2022). Brown et al. (2009) finds a large cash-flow sensitivity for R&D investments, consistent with the presence of frictions in the financing of R&D for large companies. Relative to this paper, we now also provide direct evidence that shocks to financing will affect also the composition of the investments. Krieger et al. (2022) studies the drug development industry and shows that companies experiencing positive cash-flow shocks are more likely to invest in more novel drugs. Our paper - on top of covering a broader set of companies than just the drug industry - provides evidence for a novel mechanism (i.e., the strategic interaction across companies) that may shift the type of investment undertaken by firms.

The rest of the paper is organized as follows. First, we are going to present the data used in our analysis (Section 2) and our conceptual framework (Section 3). Then, we present our empirical framework and introduce our results in Sections 4 and 5. We conclude in Section 6.

2 Data

A key limitation in studying the determinants of firms' R&D investment is the lack of data. While information on aggregate R&D spending is available for public companies, there is no systematic disclosure about how this spending is allocated across different types of investments. Furthermore, patent data cannot help overcoming this limitation. First, patents measure the ex-post outcome of the R&D process, and therefore they can only indirectly capture a change in ex-ante investments. Second, patenting activity is likely to reflect a variety of other firm-specific characteristics (Mezzanotti et al., 2022), which may be unrelated to R&D spending. As a result, it may be difficult to use this information to examine how changes in economic environment affects R&D activity, in particular when focusing on temporary changes in economic conditions.

[7] Related to this question, other papers have examined using patent data how financial frictions affect the innovation by start-ups (i.e., Howell, 2017) or smaller firms (Hombert and Matray, 2017), or examined the connection between banking conditions and productivity (e.g., Bai et al., 2018; Huber, 2018), or product introduction (e.g., Granja and Moreira, 2022). Furthermore, this contribution also relates at the literature focused on the effect of the unfolding of the Great Depression on innovation output (Babina et al., 2020a; Nanda and Nicholas, 2014).

This paper overcomes these limitations by using survey data from the US Census containing detailed information on the amount and nature of R&D investments for a large sample of US firms. Specifically, this paper combines information from two surveys: the Survey of Industry Research and Development (SIRD) for the period between 2005-2007; and the Business R&D and Innovation Survey (BRDIS) for 2008-2010.[8] There are two important aspects to highlight about this data. First, while the Census has replaced SIRD with BRDIS around 2007, the core questions in SIRD were kept in the updated product. As a result, the combination of the two surveys allow to consistently measure the amount and the quality of R&D performed by firms as well as other relevant information across the two surveys. Second, while both surveys are structured as repeated cross-sections, the data can be used to construct a balanced panel for a sub-set of large firms.[9] In fact, the sampling probability depends on the size of the company and their status as a R&D firm. As a result, large companies - in particular when active in R&D - are generally always sampled. To provide some benchmark, our final sample after matching with Compustat is made up by about 1,100 firms. More discussion on the data used is provided in Appendix (A).

This study mostly focuses on the amount of domestic R&D performed by a firm, as well as its breakdown across the type of costs incurred and type of investment. We focus on domestic performed R&D for two reasons. From a practical standpoint, this variable is the main measure of R&D activity that can be consistently measured across the two surveys. Furthermore, several of the key variables (e.g. breakdown, R&D expectations...) used in this study can be easily and consistently constructed starting from this aggregate. From a conceptual standpoint, we also think that the focus on domestic performed R&D allows to investigate the type of input to the innovation process that is the most relevant for our sample of US firms. As we discuss later in the paper (Section 4), we will also show consistent results using alternative proxies for R&D activity, like worldwide R&D performed and R&D spending.

Thanks to our data, we are able to disaggregate total R&D across its three main

[8] Similar to our paper, Foster et al. (2020) uses BRDIS combined with SIRD to understand how the type of firms investing in R&D has changed between 1992 and 2011. Instead, both Driver et al. (2020) and Mezzanotti et al. (2022) focus only on BRDIS in their analyses.

[9] While the exact sampling rules change year-by-year, both surveys tend to target the population of for-profit non-farm businesses above five employees.

components: development, applied research, and basic research. These last two categories can be combined to measure the total research effort. As discussed in Section (3), studying how changes in economic conditions affect the allocation of R&D across different types of investment is crucial to understand how the innovation path will be impacted (e.g. Akcigit et al. 2021; Griliches 1988; Link et al. 1981; Mansfield 1980, 1981). In general, the key distinction between research and development rests on whether the activity is focused on the creation of new knowledge versus the use of current knowledge and experience. According to the official documentation from the NSF, development is defined as the "systematic use of research and practical experience to produce new and significantly improved goods, services, or process." Research instead is identified as "planned, systematic pursuit of new knowledge or understanding." Within this category, the distinction between applied and basic is instead based on whether this process is conducted with specific commercial application in mind. In particular, applied is defined as an "activity aimed at solving a specific problem or meeting a specific commercial objective," while basic is "activity aimed at acquiring new knowledge or understanding without specific immediate commercial application or use." In 2007 - which is the relevant pre-period for our study - development represents the largest share of performed R&D, accounting for about 74.4% of the total. Instead, applied and basic research accounts for 21.4% and 4.2% respectively.[10]

Furthermore, we will also examine the breakdown of performed R&D across different cost types. In particular, we will examine separately the impact on labor cost, material costs, investment depreciation, and others. We discuss more about these components as we introduce the relevant tests.

Our final sample combines the information from the Census surveys to Compustat.[11] This data allows to incorporate companies' financial information to our analysis. To be precise, our analyses focus on those firms that: (a) were sampled in both 2007 and 2008; (b) were matched to Compustat; (c) are not financial firms or companies active in regulated sectors; (d) reported all the main variables used in the analysis. This leads us to consider a sample of about 1,100 firms. A detailed discussion about the variable construction and the sample creation is provided in Appendix (A).

[10]The summary statistics reported come from NSF publicly available aggregate data.

[11]Details on the matching are provided in Appendix (A).

3 Conceptual Framework

This paper examines of how an increase in the marginal cost of investing affects the quantity and quality of R&D activity. To be precise, we focus on a shift in costs that is generated by a worsening in financial conditions. The idea is that - as funding needs become more acute - the marginal cost of using internal resources increases, therefore incentivizing cuts to investments. Within this context, our interest is to understand the impact of this shock on both aggregate activity and the composition of R&D.

In general, we think that the focus on studying the connection between financial frictions and R&D investments is important for a variety of reasons. First, as we mentioned above, R&D investments are the primary input in the production function of innovation. Therefore, this study can generate important insights on the determinants of aggregate innovation in the economy. Second, while the lack of data generally forces researchers to study R&D as a monolithic category, this area is in reality characterized by a very high level of heterogeneity. While we will also explore other dimensions, our primary focus in this paper will be on the distinction between Research and Development efforts. As suggested by previous work (e.g. Akcigit et al. 2021; Griliches 1988; Link et al. 1981; Mansfield 1980, 1981), the allocation of resources between these two areas should affect firm's growth dynamics and influence the overall pattern of innovation.

Another interesting aspect is that R&D investments are very different than traditional corporate investments. To start, R&D is a human capital intensive investment activity: in 2007, 56.8% of the costs covered by aggregate R&D performed were labor costs.[12] Furthermore, the output generated by this investment is mostly intangible (Eisfeldt and Papanikolaou 2014). As a result of these features, R&D activity is generally harder to finance externally (Hall and Lerner, 2010; Kerr and Nanda, 2015). Moreover, externalities and strategic interactions are also thought to be particularly important for R&D.[13]

While a decline in R&D following an increase in funding cost may not be surprising

[12] This number comes to the NSF aggregate statistics.

[13] Companies may positively influence each other, for instance because of the presence of knowledge spillovers (Audretsch and Feldman 1996). However, the presence of races in product development or patenting (Aoki, 1991), and strong business stealing incentives may also imply that more investments from one firm could lower the return for competitors. Therefore, in practice whether investments in R&D are strategic complement or substitute (Bulow et al., 1985) depends on the specific empirical context studied.

ex-ante, there are few aspects related to this question that are worth exploring. First, despite the large array of studies on the impact of the 2008 financial crisis on the real economy (e.g. Campello et al., 2010; Cingano et al., 2016; Chodorow-Reich, 2014; Bernstein et al., 2019), relatively little is known about how this event affected innovative efforts.[14] Second, there is still a lot of uncertainty about the size of the elasticity between financial conditions and R&D (Hall and Lerner, 2010; Kerr and Nanda, 2015), both during this specific event as well as other crises.[15]

More importantly for us, theory does not provide an unambiguous prediction about how the composition of R&D changes when a firm faces a negative shock. As a starting point, we can start thinking about how different investment-specific characteristics may influence the response. In this context, one hypothesis is that managers would be more prone to cut investments with the longer duration. For instance, even when the present value of two projects is the same, myopic managers may avoid cutting activities that impact profits in the short-run (Stein, 1989).[16] In our case, development expenditure should have a more immediate impact on a firm's revenue. In fact, research – and in particular basic research - focuses on projects with high technological uncertainty, which may generate benefits only after a relative long period of time. As a result, this mechanism would predict that firms should prefer cutting research rather than development.[17]

However, the importance of this mechanism depends on the economic environment. In particular, the incentive to focus on short-term investments may be diminished or even reversed if the negative shock is experienced during a time of economic contraction. This caveat is particularly important in our case, given our focus on the 2008 financial crisis. For instance, Manso et al. (2019) shows that firms experiencing a period of declining demand may have stronger incentives to move the innovation process from exploitation to exploration.[18] Intuitively, bringing new products in a contracting market may not be

[14]This question is particularly interesting in light of the survey evidence in Campello et al. (2010), which suggests that technology investments should be among the more sensitive areas to the unfolding of the crisis.

[15]For instance, a few studies examined the impact of the Great Depression on innovation (Babina et al., 2020a; Nanda and Nicholas, 2014), but they could only look at patenting outcomes, given the lack of data.

[16]Alternatively, this preference could also be explained by the presence of rigidities in the firm liability structure or other short-run commitments, which make "short-term" cash flows more valuable.

[17]As we discuss more in Section 5.2, another alternative is that firms would prefer cutting investment with higher level of risk, as in Krieger et al. (2022). This mechanism would also likely imply a relative reduction in research relative to development.

[18]As noted by Manso et al. (2019), Schumpeter (1939) supported the idea that periods of economic

particularly beneficial. At the margin, therefore, longer-term "disruptive" projects become relatively more valuable during bad times. In our context, this force would generally favor research over development during the period studied.

Lastly, the type of response observed will also depend on the strategic incentives faced by the firm (Benoit, 1984; Bolton and Scharfstein, 1990; Fudenberg and Tirole, 1986; Opler and Titman, 1994). For instance, while slowing development activity may be less of a problem when the economy is contracting, the actual impact of this strategy will depend on whether other firms are doing the same. If we consider a model where a firm's main motivation to invest is to keep up with competitors (e.g., Harris and Vickers, 1987), its decision to cut investment in a bad economic environment depends on its expectation about what other companies will do. If the shock faced by the firm is idiosyncratic, other companies operating in the same technology space may prefer not to adjust their investments.[19] Anticipating this inability to coordinate towards lower investments, the firm may decide to avoid cutting investments or adjust less than what it would do without these strategic considerations. This intuition is similar to what you would obtain on standard investment model with externalities (e.g., Morris and Shin, 2002; Angeletos and Pavan, 2004).[20] Indeed, we later expand the parallel with this class of models to test for this channel (Section 5.2).

This mechanism – on top of affecting the overall size of the adjustment – may also influence a firm's decision about what to cut between research and development. Investments that are mostly motivated by the need to keep up with competitive pressure may be harder to reduce when a firm does not expect competitors to do the same. Whether this force will affect more research or development depends on which of these two activities is more sensitive to strategic concerns in the short-run. This idea is consistent

contraction may play an important role in increasing the focus on more productive investments. Furthermore, several models of investment can generate the same mechanism (e.g. Aghion and Saint-Paul, 1998; Caballero et al., 1994; Canton and Uhlig, 1999; Cooper and Haltiwanger, 1993; Kopytov et al., 2018).

[19]This idea is consistent with the evidence from the literature on predation (e.g. Campello, 2006; Chevalier, 1995; Cookson, 2017; Fresard, 2010; Grieser and Liu, 2019; Phillips, 1995), which shows how companies tend to exploit - not accommodate - competitors facing financial weakeness.

[20]Importantly, we are not arguing here that a firm will always decide not to cut. Instead, our argument points out that a firm in this context will (in expectation) cut less than what it would do in a model with strategic effects. Indeed, these models can be characterized by multiple equilibria if the environment lacks of any "coordinating devices." In Section (5.2), we argue that the firm-specific shocks measured in the empirical exercise - which are partially observable by other players in the market - can help firms coordinating between high versus low investments based on the average shock faced by firms in the technology space.

with the formal framework in Beath et al. (1989). In this paper, the authors highlight how R&D activities can be motivated by either "profit incentives" (i.e., the incentive to invest because of its direct benefit, irrespective from competition) or "competitive threats" (i.e., the incentive to invest in order to curb competition), and argue that the response of R&D to external shocks (e.g., government policies) will depend on which of the two forces is more important in the specific setting studied.

While we recognize the ex-ante ambiguity of this question, our intuition is that development investments are more affected by contemporaneous competitive pressure than research. By its own nature, the risk in investing in development is mostly commercial rather than technological, and these projects tend to focus on incremental improvements. As a result, the relative benefit of investing in development is more likely to be affected by what competitors are also doing during the same period. At the same time, the value of research is more likely determined by the long-term opportunities present in an industry, and should be less affected by what other companies are doing in the year. If this assumption is correct, we should expect that development investments should - all else equal - respond relatively less than research.[21]

Altogether, this discussion shows that changes in financial conditions do not have an unambiguous impact on the composition of R&D. In particular, the actual response we should expect in the data will likely depend on the investment-specific characteristics, the economic context, and the nature of the strategic interactions between firms.

4 Funding shock and R&D Investment

4.1 Research Design

The objective of our empirical analysis is to understand how an increase in the cost of funding affects R&D activity. To examine this question, we exploit variation across firms in refinancing needs at the onset of the 2008 financial crisis. To be precise, our treatment is based on the ratio between the amount of debt due within one year as of 2007 relative

[21]Note that this hypothesis will produce a similar prediction than the one based on cash-flow duration or risk. However, the mechanism would be totally different. If this hypothesis is economically important, firms' investments should also depend on what technology peers are expected to do, which in turn will depend on whether these companies are exposed to the same shock.

to the amount of cash and other liquid holdings that the company had at the same time.[22] This measure should capture the extent to which a company will likely need to access capital markets in 2008. Similar to other papers (Almeida et al. 2009; Benmelech et al. 2019; Costello 2020; Granja and Moreira 2022), the idea is that firms which enter a financial crisis with more extensive refinancing needs will experience a more significant increase in the cost of external funding, since they are forced to enter capital markets when funding options are scarce and more expensive (Santos, 2011). As a result, we expect that these companies to be more likely to undertake various corporate actions - among which cutting R&D activity - to relax the short-term cash needs.

Using this level of variation, we implement a collapsed difference-in-difference model (Bertrand et al. 2004), where we examine the change in R&D between 2007 and 2008 across firms that entered 2008 with different level of refinancing needs. In other words, our main equation is:

$$GrowthR\&D_{i,2008} = \alpha_{ind(i)} + \beta Treat_i + \gamma X_{i2007} + \epsilon_i \tag{1}$$

where $GrowthR\&D_{i,2008}$ is measured as the symmetric growth rate of R&D performed between 2007 and 2008 (Decker et al. 2014);[23] and $Treat_i$ is the treatment variable discussed above. In our main specification, we winsorize this variable at 5%, but we also show how our results are qualitatively identical when using alternative approaches. The specification also includes narrow (6-digit NAICS) industry fixed-effects $\alpha_{ind(i)}$, which allow us to control for changes in industry-level demand around the same time period. However, as we discuss later, results are similar with more conservative alternatives. Furthermore, as a further robustness, we also include a set of firm controls X_{i2007}. Specifically, we control for firm size (log revenue), profitability (ROA), and R&D intensity (R&D scaled by revenue).[24]

The crucial identification assumption behind this approach is that variation in our treatment variable in 2007 is orthogonal to a firm's investment opportunity in R&D for

[22] The variable "dd1" in the 2007 report year is used to measure the debt due within one year, while the variable "che" is used to measure the amount of cash and short-term investments available to the firm during the same time.

[23] We use the symmetric growth rate to flexibly accommodate changes in R&D at both the intensive and extensive margin.

[24] These variables are all measured at the same time as the treatment (2007). For further consistency with the treatment, we also winsorize the two ratios at the same level as the treatment.

the following year. One concern is that a firm's financial strategy at the end of 2007 may reflect its expectation about future R&D growth. In part, the plausibility of this assumption is related to the unexpected nature of the 2008 crisis. While the first signs of the weakness in the mortgage markets started to appear during 2007, the full extent of this crisis and its repercussion on financial markets and the real economy were not clear until way into 2008. As a result, it is unlikely to expect that firms knew ex-ante how the crisis would unfold and then correctly adjust their ex-ante debt position and R&D investment accordingly.

However, our data allows us to further relax this identification assumption, and therefore overcome some of the concerns typical of this approach. In fact, our surveys provide information about a firm's ex-ante expectation about the future amount of R&D investments. For example, the 2007 survey contains both the actual amount of R&D performed in 2007 as well as the expected amount of R&D to be performed in 2008. This feature allows us to isolate the impact of a change in financial condition from any difference in ex-ante expectations, therefore ruling out the leading concern discussed above. To incorporate this measure in our analysis, we augment equation 1 with the variable $ProjGrowt_{i,2008}$, which measures the expected growth rate for R&D at 2007.[25] In other words, we estimate:

$$GrowthR\&D_{i,2008} = \alpha_{ind(i)} + \beta Treat_i + \theta ProjGrowt_{i,2008} + \gamma X_{i2007} + \epsilon_i \tag{2}$$

To validate this data, in Figure (1) we plot the percentage difference between the projected and actual (ex-post) R&D for the years 2006, 2007, 2008, and 2009. This figure highlights two important features of the data. First, in regular years firms' predictions are quite accurate. With the exception of 2008, the gap between the prediction and the realization is relatively small in magnitude and statistically indistinguishable from zero. This evidence speaks to the reliability of these data in measuring firms' expectations. Second, the estimate for 2008 confirms the unexpected nature of the 2008 crisis for managers. In 2007, firms were expecting to do about 15% more R&D than what they actually ended up doing ex-post. This result is consistent with the idea that the financial

[25] In other words, we estimate the symmetric growth rate where the base year is the actual realization for 2007 and the current year is the amount of R&D expected in the 2007 survey for 2008: $\frac{(Expected_{2008} - Actual_{2007})}{(Expected_{2008} + Actual_{2007})}$. The expectation regarding R&D is expressed on domestic R&D performed, like our main outcome variable.

crisis led to a significant revision of expectations for the average firm.

4.2 Main Results

We now start presenting our results focusing on aggregate R&D in Table (1). In column 1, we estimate equation 1 without including any control: we find that firms that entered 2008 with higher level of debt to liquid assets experienced lower R&D growth than peer firms within the same 6-digit industry. The magnitude of this effect is significant: an increase in the ratio between debt and liquid assets by 0.5 leads to a 8% lower level of R&D growth between 2007 and 2008. Next we examine how adjusting for differences in expectations affect our results (equation 2). Controlling for the projected growth in R&D over the same period only has a marginal impact on the coefficient: in particular, the main coefficient of interest remains essentially identical to our baseline estimate (column 2, Table 1). Lastly, in column 3, we also include the firm-level controls: also in this case, the impact of this inclusion is minimal.

Consistent with our initial intuition, firms that entered 2008 with higher needs for refinancing cut more extensively R&D. As usual, the key concern is that the differences estimated in 2008 may reflect some secular trends in R&D growth across our treatment measure. To reject this hypothesis, we now examine the dynamics of the effects both before and after 2008. To start in Figure (2), we modify our analysis to focus on a longer panel and estimate whether there is evidence that our highly affected firms were changing R&D differentially before 2008. In other words, we estimate the following equation:

$$GrowthR\&D_{i,t} = \alpha_{ind(i),t} + \beta_t Treat_i + \theta ProjGrowt_{i,t} + \gamma_t X_{i2007} + \epsilon_{i,t} \tag{3}$$

where t is equal to 2006-2009, and represents the post-year in the growth rate.[26] The results support the quality of our setting: firms entering the crisis with high level of debt to liquid assets were not characterized by different trends in R&D growth in the years leading to the crisis. The effects estimated for the years leading to the crisis are both very small in magnitude relative to our main estimate and statistically non-different than zero at the conventional levels. While Figure (2) does not include any firm level controls, Figure (A.1) in Appendix confirms the same results including also firm specific controls

[26] In other words, $GrowthR\&D_{i,2006}$ is the growth rate between 2006 and 2005. Since this analysis is now estimated with a panel of firms, we estimate our standard errors clustered at firm level.

interacted with time dummies.

It is important to point out that the analysis discussed above is the first-differenced equivalent of the typical trend analysis conducted with data in levels. Said that, our model allows us to relax even further the identification assumption and also include firm-specific effect to the equation (3) above, therefore removing differences in the average growth in R&D across firms during the period studied. The cost of this inclusion is that we have now to normalize one year to zero, and therefore coefficients should be read as deviation relative to a baseline rate. Figure (A.2) reports the result: like before, we continue to find the main effect on R&D in 2008, but no differential growth rate relative to the baseline in 2006.

These analyses also allow us to examine what happened to firms that cut R&D in 2008 in the following year. Across the three specifications discussed above, we consistently find a null effect on the 2009 coefficient, which estimates how the growth rate of R&D evolved between 2008 and 2009 across affected firms. This null effect implies that the 2008 cut in R&D was not followed by higher growth in R&D the following year. In other words, firms that cut R&D in 2008 did not simply postponed investment to the next year. The discussion on labor cost will provide some insights on the potential reason for this behavior.

In the next Section, we will explore more these core findings, and provide further evidence consistent with the validity of our experiment.

4.3 Robustness and Other Analyses

We start by presenting some important robustness tests. In Table (A.1) we show that our results are robust to consider alternative transformations of the treatment variable. As mentioned before, our main treatment variable is winsorized at 5% to deal with possible concerns regarding the skewness of the treatment variable. To start, we show in columns 1 and 3 that winsorizing at 1% provides similar results. Next, we also show similar results when using a flexible Box-Cox transformation (Box and Cox 1964): this approach provides a data-driven way to transform a variable in order to maximize the goodness-of-fit of the variable in the specific model studied. Among the others, one advantage of this approach is that it delegates to a statistical model the selection of the right transformation, therefore minimizing the degree of freedom of the researcher.[27] As we show in columns 2 and 4, our key findings can be replicated well with this alternative approach.[28] Altogether, the transformation of the treatment variables appears to play a small role in our effects.

Next, we examine whether the results are affected by the type of industry fixed-effects included. As we mentioned before, our baseline analysis includes the tightest possible fixed-effects in our context (i.e. six-digit NAICS). While we think that this approach is best suited to control for changes in industry demand or R&D investment opportunities around the period considered, we are also mindful that this setting may be overly conservative and remove some relevant variation in the data. In Table (A.2), we report an analysis where we use broader fixed-effects definitions (i.e. 4-digit NAICS) across all three treatment definition considered in the paper. Across all three analyses, we find that our estimated coefficients are almost identical - in terms of both statistical significance and magnitude - to those estimated in the baseline.

Lastly, we also show that we can replicate our results focusing on alternative definition of a firm's R&D. In Table (A.3), we present our baseline analysis focusing on worldwide R&D performed (columns 1 and 3) and worldwide R&D expenditure (columns 2 and 4). As mentioned above, one caveat with this analysis is that - at best of our understanding - these variables cannot be perfectly reconstructed in a consistent way across the two surveys (Appendix A). While there is no reason to expect that this measurement issue will bias our estimates, it may impact their precision. In any case, we find similar results across the two alternative outcomes. While as expected the magnitude changes a bit outcome by outcome, the general message is unchanged.[29]

Before moving forward, we want to present two analyses that provide a useful validation for our narrative. First, we test whether our main result changes once we control for other firm-specific measures of financial strength. Our main argument is that the ratio between debt due and cash generates variation in the need of external

[27]The model essentially finds a parameter γ which could be applied to a variable x- such that $\frac{x^{\gamma-1}}{\gamma}$- to maximize the fit of a model considered. To estimate the optimal transformation, we use the baseline model without controls. After this first step, we apply the transformation to our original variable and use it in our model.

[28]For consistency, we adjust the transformation of controls across models. When we use the 1% winsorization, we apply the same approach to the two ratios; with the Box-Cox transformation we instead leave controls raw in line with the first stage of the Box-Cox estimation.

[29]We cannot conduct the same analysis across the breakdown discussed below. However, the similarity in this aggregate result gives us confidence that results will likely be similar.

funding in 2008. However, the amount of short-term debt due should reflect in equilibrium other aspects of the firm's balance sheet, and in particular a firm's overall ability to borrow. While this interpretation is not necessarily at odds with ours, it is useful to understand whether our results are simply reflecting balance sheet capacity in a time of crisis, rather than a short-term increase in funding needs. To explore this issue, in Table (2) we augment our baseline models with two controls that could proxy the balance sheet strength of the firm: asset tangibility (e.g., Almeida and Campello, 2007) and the firm's leverage ratio.[30] Our analysis confirms that these extra controls do not significantly affect our main coefficient. In particular, we find that our main estimated effect is effectively unchanged both when these variables are included alone and together. This suggests that the variation used in our estimation appears to be orthogonal to the one generated by these proxies of balance sheet strength.

Second, we examine which type of cost was cut the most in the response of the external shock. According to aggregate data from NSF in 2007, around 56.8% of the costs related to R&D performed are employee compensation and related benefits. The rest is material cost (11.7%), equipment depreciation (3.9%), and other costs (27.6%). To the extent that the cut documented above had a real impact on the R&D process of a firm, we should expect that a significant portion of this cost would actually come from a reduction in labor costs. In fact, other costs (e.g. material costs) are easier to scale up and down, and their cut is less likely to have a persistent impact on the nature of innovation produced by the company.

We examine this question in Table (3): this table reports the results from our model focusing on the growth rate of each sub-component of the R&D performed by the firm.[31] Our treatment predicts a very strong negative response for labor costs, material costs, and also in the residual cost category. At the same time, we find no evidence of a decline in capital investments. Table (A.4) in Appendix confirms the same results when including controls. Importantly, the magnitude of these effects imply that the decline in labor costs

[30] Asset tangibility is measured as the share of fixed assets in the balance sheet, while the leverage ratio is calculated as the ratio between long-term debt (due over one year) to total assets. Notice that the measure of asset tangibility was missing for a very small subset of firms: to avoid issues with disclosure, we replace the missing values with zeros, but then also include in the regression a dummy variable that flags these replaced observations.

[31] As throughout the paper, we use a symmetric growth rate in the outcome. Notice that the sum of the four components aggregate by construction to the total domestic R&D performed by the firm in the year.

explain about two third of the overall reduction in R&D.[32] Given the stickiness of labor relationships and the costs generated with adjusting labor (in particular when looking at high-skilled labor like the one involved in R&D), it is not surprising that the cut in R&D was not undone in the near future.

Altogether, firms entering the 2008 crisis with higher refinancing needs cut R&D more extensively. This effect is sizable, and it is robust to a variety of validation tests. Furthermore, our results also suggest that the shock significantly impacted the innovation processes within the firm. First, we have shown that the 2008 decline does not simply reflect a shift of investments in the near future. Second, the reduction is mostly achieved by reducing R&D workers' cost.

5 R&D Allocation

5.1 Research vs. Development

While understanding how a worsening in financial conditions affects R&D is an interesting issue per se, the key objective of this empirical exercise is to explore how this change in R&D activity is allocated across different types of investments. In this sub-section we start investigating this question by focusing on the whether the decline documented is coming from research or development.

In Table (4), we replicate our baseline analysis focusing on the growth rate of research and development separately. To start, we find that companies with high refinancing needs cut extensively research efforts (column 1): a 0.5 increase in the debt to cash ratio leads to an almost 14% lower growth in research between 2007 and 2008. When we include firm controls (column 3), the effect size is - if anything - slightly larger. In contrast with this result, we find no evidence that development activity was curtailed (column 2). The estimated effect is negative, but very small in absolute magnitude. Furthermore, this parameter is very small relative to its standard errors. Also in this case, the inclusion of controls do not change our conclusion (column 4).

This evidence suggests that firms responded to the need to cut R&D almost entirely by reducing research efforts, while keeping development constant. As discussed earlier

[32]To estimate this back-of-the-envelope number, we combine our estimated coefficients with information of the breakdown of costs in 2007, as reported by the NSF aggregate data.

(Section 3), this result is important as it suggests that this event was not neutral relative to the allocation of resources, but instead shifted R&D activity towards development.

As discussed in Section (3), one possible interpretation of this result is that companies may prefer to avoid cutting development because this adjustment may have a significant impact on revenues in the short-run. Instead, the negative consequences of cutting research may be only perceived over the long-run.

One way to explore this hypothesis is to go deeper within research activity and study how the shock differentially affected basic versus applied research. If the difference in cash-flow timing is the main reason explaining our findings, we should find the same results when comparing applied and basic research. In particular, we should expect the decline in research to be driven by basic research. By its own nature, basic research is conducted without an ex-ante clear commercial application. Therefore, among R&D activity, this type of projects are the least likely to have any effect on revenues over the near future.

We explore this hypothesis in Table (5). Inconsistent with the prior discussed above, we find that companies that entered the crisis with more debt due cut both basic and applied research. The magnitude of the effects is actually quite similar across the two outcomes: if anything the effect appears to be larger for applied. This result is at odds with the hypothesis discussed above.

This evidence also appears inconsistent with a risk-based explanation. Krieger et al. (2022) finds that drug companies are more likely to develop novel drugs after a positive shock to the firm's cash-flows. This evidence is interpreted as suggesting that companies are willing to take riskier bets on new products only when their overall risk declines. At face value, our evidence on the composition of R&D appears consistent with this story: as financing frictions increase, companies shift away from research activity, which is exactly the part of the budget funding projects characterized by higher risk and novelty. However, also in this case, our comparison between basic and applied research is inconsistent with this hypothesis.

Altogether, the within-research evidence appears at odds with a simple explanation based on the timing of the cash-flows or risk. To be clear, our argument is not that these mechanisms are completely unimportant, but rather that they are unlikely to be the leading force behind our findings. Furthermore, the large response within basic research also provides further validation for our results. First, basic research represents an area of the R&D portfolio that is considered particularly important for innovation (Akcigit et al., 2021). Second, given that companies also cut basic research — which is a category that is very distinct from development — it is not very likely that mis-measurement between these R&D components may play a role in explaining our results.

5.2 Investment Response and Strategic Interaction

As we discussed in Section (3), another possibility is that the heterogeneous response between research and development may in part reflect the strategic incentives faced by firms. This result would be consistent with our initial hypothesis that the value of development investments is largely about fending off competitive threats. As a result, firm behavior in this area is mostly determined by the expectation about competitors' behavior: if competitors are expected to invest heavily, deviating from the same strategy could be expensive. This indeed would imply a smaller elasticity of investment in development to firm-specific shocks.

To provide further evidence about this mechanism, we examine another implication of this framework: a company's investments should be impacted by the expected behaviors of other firms operating in the same technology space. Our hypothesis is that the limited response in development stems from the inability of firms to coordinate towards a "low investment" equilibrium when shocks are idiosyncratic (i.e., large refinancing need for one company does not necessarily imply higher needs for its competitors). However, this prediction can be refined if we consider the firm refinancing need - which is (at least partially) observable ex-ante by the market – as a noisy signal of a firm's benefit of cut investment. In this model, the average shock experienced by firms within a technology space can act as a public signal (Morris and Shin, 2001) and facilitate coordination. Irrespective of the firm's specific refinancing need, this setting should predict that companies will cut development if the average shock experienced by firms within the same technology space is sufficiently large.[33]

[33] To be clear, our claim is not that the firm-specific shock should be completely irrelevant. Empirically, our estimate for the effect on development is statistically non-significantly different than zero, but we cannot exclude that the effect is just too small to be detected. Furthermore, in this type class of models (e.g., discussion on public signals with a continuum of firms in Morris and Shin (2001)), the relative importance of the firm-specific shock versus the average shock of competitors depend on the relative precision of the two "signals" in predicting the underlying parameter of interest. Our case is a perfectly symmetric game,

To implement this test, we measure for each firm in our data the average exposure to the same shock (i.e. the refinancing need) for the set of firms that technologically close. To start, we follow Bloom et al. (2013) and use patent data in the ten years before 2007 to estimate a measure of technological proximity among all firms in our sample. In particular, this measure $Closeness_{ij}$ takes value between zero and one, where zero characterizes a pair of firms with no technological overlapping and one identifies companies that operate exactly in the same technological space (Appendix A). With this measure on hand, we then construct a firm-specific proxy for the exposure of peers; this measure is simply the weighted-average of our baseline treatment measure across all firms in the sample but the firm itself, where the weights are the proxy of the technological proximity estimated above.[34]

Then, we extend the previous empirical model by including both the direct exposure and the competitors' exposure to the financial shock in the equation (2). The results are provided in Table (6). In column 1, we examine the result of this analysis for aggregate R&D. While the estimated direct effect is effectively unchanged relative to the baseline analysis, we now also find evidence of an indirect effect in the R&D adjustment. Consistent with the conceptual framework discussed in Section (3), a firm cuts R&D more extensively when its technology peers are also experiencing higher refinancing needs, and this effect adds on the firm's direct response.

Next, we show that - unlike our main effect - this response is driven by an adjustment in development, rather than research. In column 2, we show that research spending is not affected by the financial conditions technology peers. In column 3, we show that this result is reversed for development. As documented in baseline analysis, there is no direct effect of the shock of development growth. However, the exposure to peers' financing shock significantly affect development: on average, firms are more cutting more extensive development when its technology peers are likely to be constrained.[35] This evidence is consistent with our initial hypothesis: consistent with the null direct effect

and therefore it is plausible to expect the average signal –which aggregates information across several firms – to be much more informative than the firm-specific one. Said that, this feature does not have to be plausible in every scenario.

[34] In other words, the measure is: $TreatComp_i = \frac{\sum_{j \in C_i} Closeness_{ij} Treat_j}{\sum_{j \in C_i} Closeness_{ij}}$. To measure the treatment $Treat_j$, we use the same variable as the baseline. For each firm, the set C_i is defined as all other firms in the data but the firm itself.

[35] Results are effectively the same without controls as reported in Appendix Table (A.5).

on development, we find that development activity is strongly affected by competitors' behavior.

Altogether, firms adjusted their R&D investment mostly by cutting research, while maintaining development constant.[36] While our evidence does not exclude that other factors could also be important, it suggests that strategic concerns could play a role behind this heterogeneity.

6 Conclusions

This paper studies how an external shock to funding affect how US firms conduct R&D activity. To examine this question, we focus on the 2008 financial crisis and take advantage of a series of Census surveys on R&D. This data allows us to focus on both the overall quantity of R&D performed by firms as well as study the allocation of R&D across different types of activities.

To start, we show that companies that entered 2008 with a higher amount of debt due in that year relative cash responded to the worsening in financial conditions by cutting R&D. This effect is robust to a variety of tests and it is not driven by ex-ante differences in expectations about the future of the economy. We also show that a significant portion of the cut is achieved by reducing R&D employment costs. Consistent with the idea that adjusting labor is expensive, we find that the decline documented in 2008 is not compensated by higher R&D in the following year.

We then show that the cut is almost entirely achieved through a reduction in research. Specifically, we find that firms facing higher refinancing concerns significantly cut research performed, but left development roughly unchanged. We argue that this difference does not simply reflect the different duration or risk of the two types of investments. If companies were simply more keen to cut the investment with longer duration (or riskier), we should also observe larger cuts for basic research relative to

[36]We note that our approach is qualitatively equivalent to estimating the across firms spillover effects research and development in reduced form, as discussed in Huber (2022). As noted in this paper, this approach may be biased by the presence of measurement errors or multiple spillover dimensions. However, following the argument in Huber (2022), this concern is likely to be second-order in our context, given the large difference in estimate between the effect for research and development. In fact, the main sources of bias in our context are likely to affect similarly both the estimates for research and development, and therefore they would generally induce the two effects to be similar.

applied. Instead, we find that both types of research activity are cut by a similar amount.

We argue that strategic concerns may - at least partially - explain why development is less responsive than research in our setting. For each firm in our sample, we construct a measure of exposure to the refinancing shock for firms that are operating in the same technology as the focal firm. We then document that the amount of development performed by the firm - while it is unaffected by the firm-specific refinancing needs - is reduced when peer firms are experiencing a negative shock. The same result does not hold for research. In other words, development appears to be more sensitive to the behavior of peers, while research is only driven by firm-specific economic conditions. This evidence is consistent with the idea that competitive pressure may prevent firms to adjust their development activity, therefore generating the response documented above.

Altogether, our paper shows that periods of crisis will not only determine the aggregate amount of investments, but also affect its composition. In our case, the unfolding of the financial crisis in 2008 may have increased the relative importance of development relative to research efforts for US firms. Furthermore, we also highlight the importance of competitive forces to shape the type of response. While investment-specific characteristics are important to determine a firm's decision during the business cycle (e.g. Benmelech and Bergman, 2011; Eisfeldt and Rampini, 2007; Ma et al., 2021; Rampini, 2019), our evidence suggests that the nature of interaction between peers may also significantly affect the behavior.

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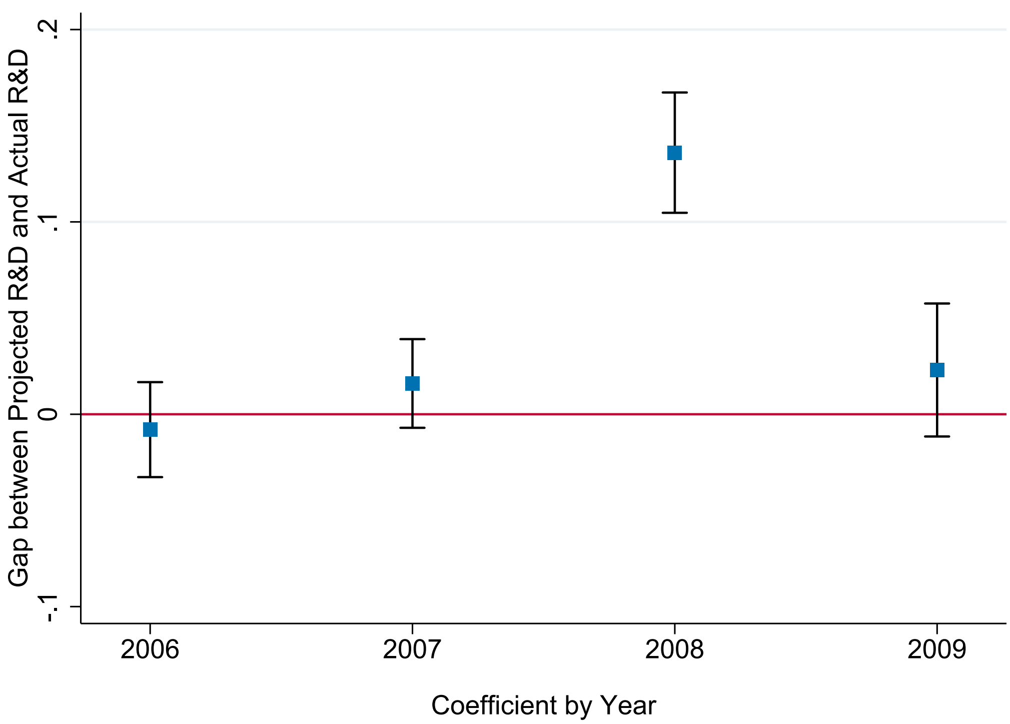
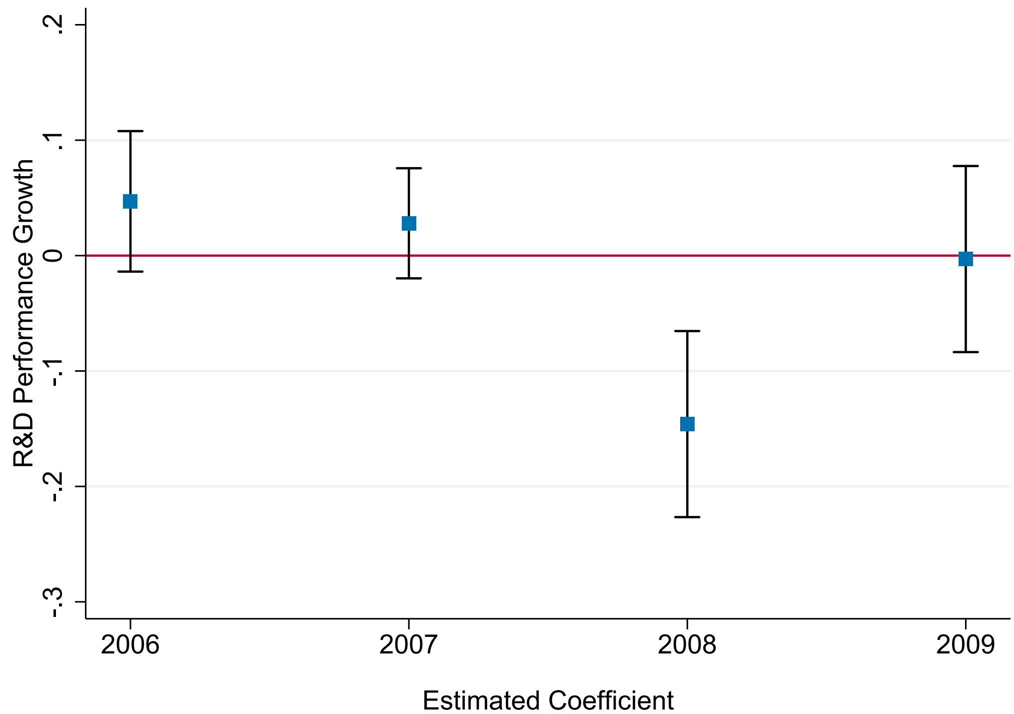
Figure 1: Percentage Gap: Actual vs. Expected R&D



This figure plots the average percentage difference between actual domestic R&D performed by a firm and its prediction.

Figure 2: R&D and Financing Need in 2008: dynamics



This Figure reports the coefficient from the estimation of equation (3). The outcome is yearly R&D growth, considered over the period between 2006 and 2009. To be clear, the growth rate is calculated between the year reported in the y-axis (post) and the year before. The coefficient reports the year-by-year effect of our main treatment variable on the outcome, with the corresponding 95% confidence interval. Industry-by-year fixed effects are included as well as the contemporaneous control for projected R&D. Standard errors are clustered at firm-level.

Table 1: R&D and Financing Need in 2008

	(1)	(2)	(3)
Debt/Cash	-0.165^{***}	-0.141^{***}	-0.150^{***}
	(0.051)	(0.049)	(0.048)
Proj R&D		X	X
Log(Revenue)			X
ROA			X
R&D/Asset			X
Industry Effects	Yes	Yes	Yes
Obs	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2). The outcome is the symmetric growth rate for domestic R&D performed between 2007 and 2008. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. In column (1), we provide the baseline analysis where the only other control is the set of narrow industry fixed-effects. In column (2), we include our measure of projected R&D growth as of 2007, as described in the main text. In column (3), we augment the specification in column (2) with the listed set of firm level controls. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table 2: Funding Gap vs. Balance Sheet Strength

	(1)	(2)	(3)
Debt/Cash	-0.139^{***}	-0.149^{***}	-0.139^{***}
	(0.048)	(0.048)	(0.049)
Leverage	Yes		Yes
Tangibility		Yes	Yes
Projected Growth	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Obs	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of the full version of equation (2). The outcome is the symmetric growth rate for domestic R&D performed between 2007 and 2008. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Each specification includes narrow industry fixed-effects as in the baseline. We also include always the standard controls. On top of this, we now include a measure of total leverage in 2007 (column 1), measured as total long-term debt over asset; a measure of asset tangibility in 2007 (column 2), measured as the share of fixed assets and total assets; and both variables (column 3). Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table 3: R&D Adjustment Across Types of Costs

	(1)	(2)	(3)	(4)
Debt/Cash	-0.162^{***}	.016	-0.149^{*}	-0.216^{**}
	(0.051)	(0.083)	(0.084)	(0.104)
Firm Controls	Yes	Yes	Yes	Yes
Projected Growth	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Outcome	Wages	Inv.Depr.	Mat. Costs	Oth. Costs
Obs	1100	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2). The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider four different outcomes, which measure a specific component of R&D along the cost dimension. In particular, in column 1 we measure R&D performed used to cover labor costs; in column 2 we focus on the R&D that covers investment depreciation; in column 3, we consider R&D covering material costs; in column 4, we consider R&D covering other costs, which is a residual category. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Each specification includes narrow industry fixed-effects as in the baseline. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table 4: Research versus Development

	(1)	(2)	(3)	(4)
Debt/Cash	-0.274^{**}	-.03	-0.322^{***}	-.028
	(0.113)	(0.079)	(0.112)	(0.080)
Firm Controls			Yes	Yes
Projected Growth	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Outcome	Research	Development	Research	Development
Obs	1100	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2). The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider separately R&D performed that focuses on actual Research (columns 1 and 3) and Development (columns 2 and 4). The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Each specification includes narrow industry fixed-effects as in the baseline. Columns 3 and 4 also include firm-level controls, as in the baseline model. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table 5: Applied versus Basic Research

	(1)	(2)	(3)	(4)
Debt/Cash	-0.203^{**}	-0.291^{***}	-0.217^{**}	-0.339^{***}
	(0.098)	(0.112)	(0.099)	(0.112)
Firm Controls			Yes	Yes
Projected Growth	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Outcome	Basic Res.	Applied Res.	Basic Res.	Applied Res.
Obs	1100	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2). The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider separately R&D performed that focuses on actual Basic Research (columns 1 and 3) and Applied Research (columns 2 and 4). The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Each specification includes narrow industry fixed-effects as in the baseline. Columns 3 and 4 also include firm-level controls, as in the baseline model. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table 6: R&D and Financing Need in 2008: Direct and Indirect Effects

	(1)	(2)	(3)
Debt/Cash	-0.152^{***}	-0.328^{***}	-.026
	(0.048)	(0.112)	(0.080)
CompShock	-0.779^{**}	.245	-1.182^{**}
	(0.365)	(0.769)	(0.538)
Unconnected Dummy	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes
Projected Growth	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Outcome	Overall	Research	Development
Obs	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2) augmented by the average financing need of competitors, as discussed in the paper. The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider total R&D performed (column 1), only Research (column 2) and only Development (column 3). The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. We also include the variable capturing the weighted-average of the financing need for all competitors, where the weights are measured based on the technological proximity between the firm and all possible competitor. Each specification includes narrow industry fixed-effects as in the baseline. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Research and/or Development? Financial Frictions and Innovation Investment

Filippo Mezzanotti and Tim Simcoe

Appendix

A Data Appendix

In this Appendix, we discuss in more details the data construction.

A.1 R&D Survey Data

The core data used in our empirical exercise is constructed by combining the output of the Survey of Industrial Research and Development (SIRD) and Business Research & Development and Innovation Survey (BRDIS). As we mentioned in the paper, SIRD is a survey of R&D that was run from 1972 to 2007, and was replaced by BRDIS starting from the 2008 data release. In terms of data construction, there are two key features of these surveys that are important to highlight. First, while the original survey output is as a repeated cross-section, large companies - in particular when active in R&D - are very likely to be surveyed every year. Public documentations provide a more complete description of the sampling procedure, however we provide here a short description. In general,firms are classified into three strata: known positive R&D, known zero R&D, and unknown R&D. The largest firms from each strata are sampled with certainty.[37] This is either done by an R&D threshold, by a revenue threshold, or by being a large firm across each state (top 50 in sales). While the exact procedure changes year-by-year, this process implies that most large companies should be consistently sampled. In our analysis, we will focus on a consistent set of firms that is sampled both in 2007 and 2008, and we are able to follow their R&D activities between 2005 and 2009.

[37]The actual final sampling happens at the establishment level, rather than firm level. As a result, there are a few cases in the data of the same company having more than one establishment sampled. In this project, this is not an issue because we will match the data at Compustat data, therefore allowing us to preserve the firm-level structure of the sample. Furthermore, also among the full sample, the number of cases is quite limited.

Second, despite the switch between BRDIS and SIRD, the core questions from SIRD are maintained also in BRDIS. As it is discussed more extensively in Mezzanotti et al. (2022), BRDIS can be considered as an extension of SIRD, which explores more in depth dimensions of the innovation activity that were missed in the early survey. For instance, among the other things, BRDIS contains a wider set of questions that cover issues like the use of intellectual property. For our study, a key aspect is that the data allows us to measure consistently the domestic R&D performed by the firm over time.[38] While there are also conceptual reasons to focus on this specific measure of R&D inputs, our choice is also motivated by practical reasons. First, at best of our understanding, this aggregate is the only measure of total R&D inputs that can be consistently measured over the period considered.

Second, several relevant other measures used in the paper can be easily constructed relative to this quantity. In particular, we can split this measure based on the type of project that is covered by the investment. As we discussed in detail in Section 2, the survey allows us to measure consistently how R&D performed is split between applied research, basic research, and development.[39] Similarly, we can also reconstruct how the investment was used to cover specific type of costs. We specifically divide costs across four categories: labor costs, investment depreciation, material costs, and others. Labor cost is a combination of both wages and benefits, which are measured separately in both SIRD and BRDIS.[40] The variable "other costs" is a residual category: this is measured directly in SIRD, and it is created by us in BRDIS by aggregating all costs that were not covered in the other categories.[41]

Another advantage of domestic R&D performed is that for this quantity we can also measure the company's projections for the following year. In other words, a company in year t is asked about how much R&D is expecting to perform in $t + 1$. This variable is available in SIRD for all years and in BRDIS up to 2009 (i.e. the 2010 projection). As we

[38]The question is asked with a slightly different format over time: however, the actual content should actually be perfectly consistent over time.

[39]While these quantities can be constructed consistently across the years, some work is necessary to achieve this goal because the structure of the underlying question changes from year-to-year. For instance, in 2008, the question asks to breakdown across the categories as a percentage of the total R&D performed, while in the other years it asks the same question in dollar.

[40]BRDIS 2008 actually provides a more detailed breakdown of this quantity.

[41]This breakdown is not available for our full sample. However, both samples are approximately made up by 1,100 (following the rounding guidelines of the Census).

discuss in the paper, we use this variable to separate the effect of the shock from possible differences in ex-ante expectation among along the treatment variable.

We also replicate our results using two alternative measures of a firm's R&D inputs: worldwide R&D performed and worldwide R&D expenditure. One limitation of these variables is that we are not able to undertake all the breakdown analysis discussed. Furthermore, it is not clear that these variables can be constructed in a perfectly consistent way across SIRD and BRDIS. For instance, when we look at worldwide R&D performed, this variable is directly measured in BRDIS. In SIRD, we can proxy it by summing domestic R&D performed and a variable measuring the R&D performed outside the US by subsidiaries for which the firm owns more than 50%. At best of our understanding, this second component may not be exactly consistent with the definition in BRDIS of what was undertaken abroad. For worldwide R&D expenditure, we face the same issue: while this quantity is measured directly in BRDIS, it is not clear that our data allows us to measure the amount of R&D that the company paid abroad when performed by firms that are not subsidiaries. While it is important to highlight these limitations, we also want to report that ex-post these differences are likely not first order (Section 4), since our estimates are very consistent across all of them.

We undertake an extensive data management process to confirm the quality and improve the coverage of our data set.[42] Given that the structure of the exact questions and the variable labels may change across surveys, we manually re-code all variables and construct aggregate that are consistent across years. Furthermore, while not very frequent, we also impute some missing variable, when we are confident that this information should actually be present. For instance, there are some cases where detailed R&D questions are missing but the firm reports null but non-missing total worldwide R&D. In these cases, we make sure that the variables that breakdown R&D across categories are set to zero if the firm reports the total to be zero. A special note has to be made for the 2008 survey: the survey had a check box at the very beginning asking if a company has done or paid any R&D activity. If the answer is no, the respondent skips most of the survey and only answers the second part about intellectual property. As a result, we need to set to zero all measures of R&D investments as well as R&D employment when a firm has checked the box and then responded to the questions about intellectual property.

[42]Our starting point we use the edited version of each reported variable.

Furthermore, to guarantee consistency in terms of sample size across outcomes, we replace missing at breakdown variables when we have the total and all but one component. We make an example to clarify this point: assume we have information on both applied and basic research and total R&D performed, but for some reason development is missing. By the definition of these variables, we can replace the missing with the difference between total R&D and research. The same logic can apply to other combination of variables. In general, these adjustments are relatively rare relative to the full sample, and they are even more uncommon (if present at all) once we consider the final sample, which also matches the data to Compustat.

In the end, our final sample covers firms that: (a) were sampled in both 2007 and 2008; (b) were matched to Compustat (as described below); (c) are not financial firms or companies active in regulated sectors;[43] (d) reported all the main variables used in the analysis.[44] This last filter has been imposed to make sure we satisfy the disclosure requirements for the Census: specifically, we want to make sure that our sample size does not change across different specifications and outcomes, therefore potentially identifying small implicit samples.

A.2 Other data sets

There are two external data sets that are also used in the paper.

First, to incorporate measures of financial conditions, we match our survey data to Compustat in order. To be clear, we are conducting the matching using the full R&D survey, before zooming on the financial crisis period. After a preliminary cleaning of Compustat,[45] we have first matched this data set to the Standard Statistical Establishment List (SSEL) (Miranda et al., 2006).[46] We conduct this procedure in different steps, and each step we remove all matched firms from the sample.[47] In the first step, we match based on the year and the EIN, which is reported in both samples. This step successfully

[43]We exclude firms with NAICS within 52, 92, and 813/814.

[44]As discussed in Mezzanotti et al. (2022), we exclude foreign firms from the R&D surveys.

[45]In particular, we remove from Compustat 2002-2016 duplicates information, ADRs and other non-standard firms, financial vehicle and royalty trusts (firms within NAICS 5221, 5239, 5259, 5311, 5331 with zero or missing employment), firms without revenue and assets. We also removed firms without NAICS or reported with fewer than 4-digit.

[46]We combine together SU, MU, and MA datasets.

[47]To be precise, we drop from SSEL all establishment within the same firm when one establishment matches.

matches more than half of the data. Subsequently, we proceed at matching based on the exact name after cleaning and standardizing the name, which also leads to a significant increase in coverage.[48] On the remaining sample, we perform a fuzzy matching followed by a manual review of all plausible matches. At the end of the matching procedure, we perform a variety of quality checks, comparing information that should be available across the two data sets, like industry and location.

At the end, we are able to match a very large share of Compustat firms to our survey data. Once matched to SSEL, we can easily extend the matching to our combined sample of SIRD and BRDIS, and import all relevant variables. As we mentioned above, the sampling for the surveys is done at the level of the establishment. However, the Census aims to only sample one establishment per firm. However, in a very small number of cases we have more than one establishment within the same firm. This raises the question of which establishment to use. We observe that in most cases - when more than one establishment is sampled - only one answers the survey, consistent with the idea that a company has to provide only one response. Therefore, we deal with these cases by keeping the one establishment which reports non-missing sales, non-missing and positive R&D performed, when more than one is reported. If multiple establishments are still reporting after this process of elimination, we select the one establishment with the highest reported R&D. However, it is important to point out that these cases are extremely infrequently, and are unlikely to affect our inference in any way.

The second non-Census data set used in the paper is the patent data. The procedure to import this data is much easier, since we can leverage on the pre-existing linkage file developed by Dreisigmeyer et al. (2018). This file provides a direct linkage between patents and firms' identifiers available within the Census for the sample of patents granted during the period 2000 and 2015. Given the typical delay between application and grant time, this implies that our sample has a good coverage of patenting since 1997. Using this file, we import patent data from PatentsView, downloaded at the end of 2018.[49] As part of our project, we have also compared the matched patent data and self-reported measures of patenting activity in BRDIS and found that the two measures were largely consistent.

The main use of the patent data in the paper is to construct our measure of

[48]Before performing the match, we clean the names before stripping away endings (e.g. inc, corp, llc, -old), standardizing abbreviations (e.g. technology and tech), and removing special characters and spaces.

[49]https://patentsview.org/

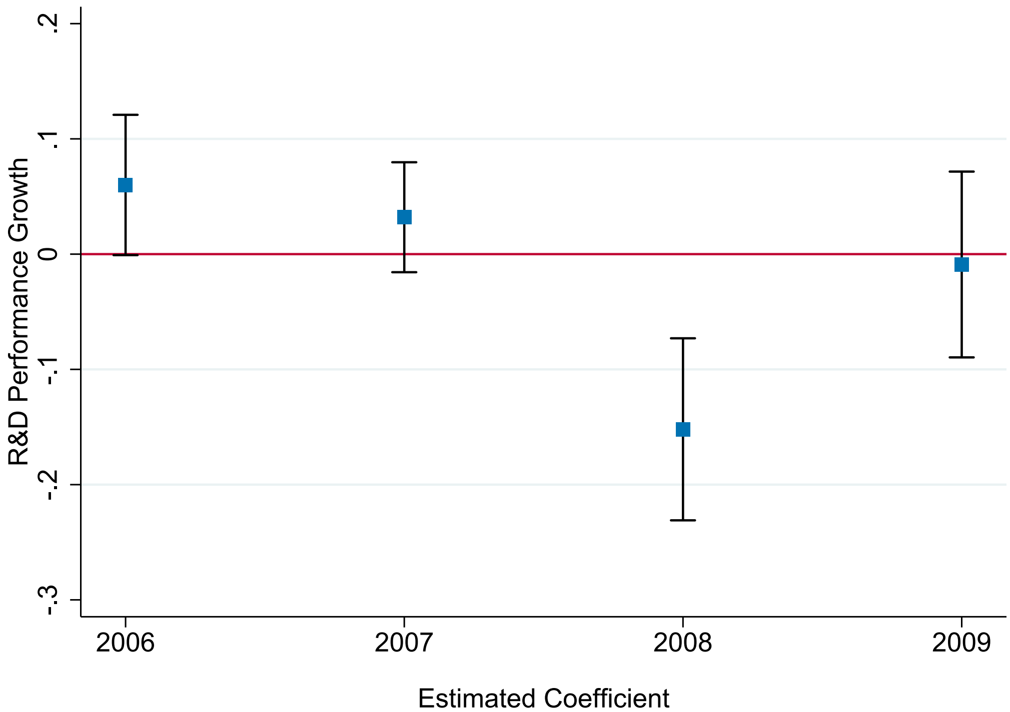
technology similarity (Bloom et al., 2013), which requires us to know both the amount of patenting activity and its distribution across technology classes. We estimate similarity across all the firms in our final data set (i.e. the sample of firms used in the main analyses). We follow the approach in Bloom et al. (2013), which effectively measures similarity by constructing the level of overlapping in patenting activity across firms. In other words, our measure takes value between zero and one, where zero characterizes a pair of firms with no technological overlapping and one identifies companies that operate exactly in the same technological space.

We then construct a firm-specific proxy for the exposure of technology peers; this measure is simply the weighted-average of our baseline treatment measure across all firms in the sample but the firm itself, where the weights are the proxy of the technological proximity estimated above. In other words, the measure is: $TreatComp_i = \frac{\sum_{j \in C_i} Closeness_{ij} Treat_j}{\sum_{j \in C_i} Closeness_{ij}}$. To measure the treatment $Treat_j$, we use the same variable as the baseline. For each firm, the set C_i is defined as all other firms in the data but the firm itself.

An important note is that the measure of indirect treatment can only be constructed following this procedure for firms that have done some patenting during the period considered. Given the type of firm considered in this paper, almost every company in our data had applied to at least one patent, and most of them have patented extensively. For those firms that did not patent, we replace $TreatComp_i$ to be zero. However, we also create a dummy variable in our data that flags this small subset of firms, and always include this as a control when the variable $TreatComp_i$. We have followed this approach because it allows us to keep the sample consistent across analyses, therefore avoiding disclosure concerns about the presence of small implicit samples.

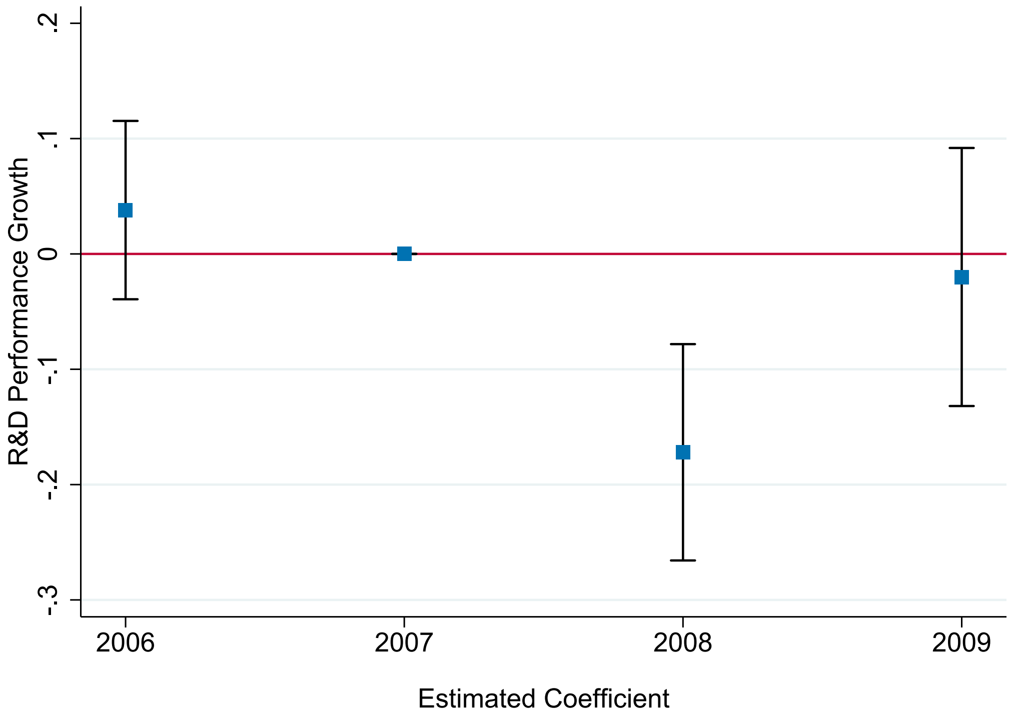
B Appendix Figures

Figure A.1: R&D and Financing Need in 2008: dynamics with firm controls



This Figure reports the coefficient from the estimation of equation (3). The outcome is yearly R&D growth, considers over the period between 2006 and 2009. To be clear, the growth rate is calculated between the year reported in the y-axis (post) and the year before. The coefficient reports the year-by-year effect of our main treatment variable on the outcome, with the corresponding 95% confidence interval. Industry-by-year fixed effects are included as well as the contemporenous control for projected R&D. Relative to Figure (2), we now include also the firm control in 2007 (as in the main analysis). Standard errors are clustered at firm-level.

Figure A.2: R&D and Financing Need in 2008: dynamics with firm fixed-effects



This Figure reports the coefficient from the estimation of equation (3), where we also include a firm fixed-effects. The outcome is yearly R&D growth, considers over the period between 2006 and 2009. To be clear, the growth rate is calculated between the year reported in the y-axis (post) and the year before. The coefficient reports the year-by-year effect of our main treatment variable on the outcome, with the corresponding 95% confidence interval. Industry-by-year fixed effects are included as well as the contemporenous control for projected R&D. Because of the inclusion of the extra firm-fixed effect, we normalize the 2007 coefficient to zero. Standard errors are clustered at firm-level.

C Appendix Tables

Table A.1: R&D and Financing Need in 2008: Robustness Alternative Treatments

	(1)	(2)	(3)	(4)
Debt/Cash (W1)	-0.092^{***}		-0.090^{***}	
	(0.030)		(0.029)	
Debt/Cash (BP)		-0.083^{***}		-0.080^{***}
		(0.028)		(0.028)
Proj R&D	X	X	X	X
Log(Revenue)			X	X
ROA			X	X
R&D/Asset			X	X
Industry Effects	Yes	Yes	Yes	Yes
Obs	1100	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of equation (2), both without (columns 1 and 3) and with (columns 2 and 4) firm controls. The outcome is the symmetric growth rate for domestic R&D performed between 2007 and 2008. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007. However, in columns 1 and 2, we winsorize this variable at 1%, while in columns 3 and 4 we apply a Box-Cox transformation, as described in the paper. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table A.2: R&D and Financing Need in 2008: Robustness Alternative Outcomes

	(1)	(2)	(3)	(4)
Debt/Cash	-0.133^{***}	-0.089^{*}	-0.146^{***}	-0.103^{**}
	(0.050)	(0.049)	(0.049)	(0.048)
Projected Growth			Yes	Yes
Firm Controls			Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Outcome	World Performed	World Exp.	World Performed	World Exp.
Obs	1100	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of equation (2), both without (columns 1 and 2) and with (columns 3 and 4) firm controls. The outcome is the symmetric growth rate for a measure of R&D between 2007 and 2008. In particular, in columns 1 and 3, we consider worldwide performed R&D while in columns 2 and 4 we consider worldwide R&D expenditure. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table A.3: R&D and Financing Need in 2008: Robustness Alternative Industry Adjustment

	(1)	(2)	(3)
Debt/Cash	-0.145^{***}		
	(0.041)		
Debt/Cash (W1)		-0.078^{***}	
		(0.024)	
Debt/Cash (BP)			-0.052^{***}
			(0.018)
Projected Growth	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes
Industry Effects (4 digit)	Yes	Yes	Yes
Obs	1100	1100	1100

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

This Table reports the estimate of the full version of equation (2). The outcome is the symmetric growth rate for domestic R&D performed between 2007 and 2008. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, across the three transformations considered: 5% winsorize (column 1), 1% winsorize (column 2), and Box-Cox transformation (column 3). Relative to the other analyses, we now consider fixed-effects at 4-digit NAICS, which are therefore broader than the one considered before. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table A.4: R&D Adjustment Across Types of Costs: Robustness with firm controls

	(1)	(2)	(3)	(4)
Debt/Cash	-0.157^{***}	.028	-.141	-0.203^{*}
	(0.051)	(0.084)	(0.085)	(0.104)
Firm Controls				
Projected Growth	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Outcome	Wages	Inv.Depr.	Mat. Costs	Oth. Costs
Obs	1100	1100	1100	1100

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

This Table reports the estimate of different versions of equation (2). The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider four different outcomes, which measure a specific component of R&D along the cost dimension. In particular, in column 1 we measure R&D performed used to cover labor costs; in column 2 we focus on the R&D that covers investment depreciation; in column 3, we consider R&D covering material costs; in column 4, we consider R&D covering other costs, which is a residual category. The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. Each specification includes narrow industry fixed-effects and firm controls as in the baseline. Heteroskedasticity Robust Standard Errors are reported in parenthesis.

Table A.5: R&D and Financing Need in 2008: Direct and Indirect Effects, with controls

	(1)	(2)	(3)
Debt/Cash	-0.143^{***}	-0.274^{**}	-.031
	(0.049)	(0.113)	(0.079)
CompShock	-0.626^{*}	.356	-1.159^{**}
	(0.360)	(0.766)	(0.538)
Unconnected Dummy	Yes	Yes	Yes
Firm Controls			
Projected Growth	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Outcome	Overall	Research	Development
Obs	1100	1100	1100

*** p<0.01, ** p<0.05, * p<0.1

This Table reports the estimate of different versions of equation (2) augmented by the average financing need of competitors, as discussed in the paper. The outcome is the symmetric growth rate for the measure R&D considered between 2007 and 2008. In particular we consider total R&D performed (column 1), only Research (column 2) and only Development (column 3). The main treatment variable is the ratio between debt due in 2008 relative to the liquid assets in 2007, winsorized at 5%. We also include the variable capturing the weighted-average of the financing need for all competitors, where the weights are measured based on the technological proximity between the firm and all possible competitor. Each specification includes narrow industry fixed-effects and firm controls as in the baseline. Heteroskedasticity Robust Standard Errors are reported in parenthesis.