ABSTRACT

Title of dissertation: THREE ESSAYS ON FINANCE AND PRODUCTIVITY

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Financial crises are associated with large and persistent output losses, pointing to productivity losses. A potential channel for this phenomenon is the negative impact of disruptions in financial markets on innovative activity, since innovation is the key driver of productivity and economic growth. Throughout three chapters of my dissertation, I provide evidence for this channel. Using data from advanced, emerging market and European economies, following different financial crisis episodes, I show that financial crises lead to a persistent decline, not only in the economic output, but also in innovation. The findings in this dissertation have implciations for macroeconomic policies such as monetary and fiscal policies, structrucal reforms, crisis prevention policies and policies that can shelter productive investment projects from financial frictions.

THREE ESSAYS ON FINANCE AND PRODUCTIVITY

by

Can Sever

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It is impossible to remember all, and I apologize to those I've inadvertently left out.

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Chapter 1: Stock Market and Productivity: Evidence from the European Crisis

1.1 Introduction

Financial crises are associated with large and persistent output losses (Cerra and Saxena 2008, Reinhart and Rogoff 2009), pointing to productivity losses. A main channel for this phenomenon is the decline in R&D investment following a financial crisis, since R&D investment is the key input for innovation, and thus a key driver of productivity and economic growth. The literature has mostly focused on the effect of negative shocks to the banking system to explain channels through which financial crises can give rise to lower productivity growth, and hence lower economic growth. However, the role of the stock market in this relationship has not been studied much. This paper aims to fill this gap in the literature by investigating the role of the stock market in explaining the decline in productivity growth, through its impact on the R&D investment. This is particularly important in the case of R&D investment channel, since the previous literature found that financing R&D investment is more dependent on the stock market than the banking, due to its characteristics, such as lack of collateral value, highly skewed and uncertain returns and information asymmetries (Brown et al. 2012 and 2009, Carpenter and Petersen 2002, Hall 2002). Specifically, I focus on the fact that economic growth in European economies declined during the GFC and has remained sluggish ever since (Adler et al. 2017, OECD 2015). Although there are several recent articles that study the reasons for the persistent decline in economic growth in Europe and other advanced economies following the GFC, they focus only on the banking side. Broadly speaking, they show that weak corporate balance sheets combined with tight credit conditions have dampened total factor productivity (TFP) growth, possibly by preventing firms from investing in potentially productive assets (Ahn et al. 2018, Kalemli-Ozcan et al. 2018 and Duval et al. 2017). However, the role of stock market in this phenomenon in the aftermath of the GFC has not been studied yet. In this study, I show that developments in the stock market had a large and persistent effect on both R&D investment and productivity growth in European countries following the GFC. This does not rule out the role of the banking system in the sluggish economic growth found by recent studies. Rather, the findings in this paper add to those previous findings, and suggest that policies that address stock market can also play a crucial role in alleviating economic losses and facilitating economic recovery from financial crises.

Developments in the stock market are crucial in explaining the changes in R&D investment. There are several reasons why financing through stock market, i.e. external equity financing, may be more appropriate for R&D projects than credit. First, returns on innovative projects are highly skewed and uncertain, partly due to that R&D projects have low probability of success. Creditors do not share the return in good states of nature, and hence "lenders are only concerned with the bottom part of the tail of the distribution of returns" (Stiglitz, 1985). In contrast, investor's upside return is not bounded in the case of external equity financing. Second, information asymmetry is a problem to a larger degree in R&D projects, since such projects are hard to evaluate and require new knowledge. In this case, creditors may ration credit, rather than charging higher interest rates, as discussed by Stiglitz and Weiss (1981). Thus, debt supply can become vertical at very low levels of leverage and impose a financial constraint to fund R&D projects. As an alternative source of funding, external equity financing can relax this financial constraint though (Carpenter and Petersen 2002). Third, R&D projects are highly intangible and thus have limited collateral value. Given that debt financing requires collateral, lack of collateralizable assets restricts the ability to raise debt financing for R&D projects. In sum, adverse selection problem, financial distress and limited collateral value make debt financing a poor substitute for external equity financing for R&D projects.

There is plenty of evidence in favor of this idea that R&D investments rely more on external equity financing than debt financing, and hence developments in the stock market is more important for financing R&D projects than the banking. Aghion et al. (2004) find that firms with larger R&D expenditure have lower leverage and larger probability of new equity issuance in the case of UK firms. Muller and Zimmermann (2009) focus on small and medium-sized enterprises in the case of Germany, and show that firms with increasing R&D intensity have larger external equity financing, together with lower banking credit. Martinsson (2010), using data from European firms, find that innovative firms raise more capital from stock markets than from debt financing. Similarly, Brown et al. (2012) use firm-level data from 16 European countries from 1995 to 2007, and find that external equity financing is more important for R&D intensive firms than banking credit. They conclude that stock market development can play an important role for innovation and productivity growth in Europe. There are similar evidence for the US too. Carpenter and Petersen (2002) use data from publicly listed firms in the US over two decades and find that external equity financing plays a crucial role for the rapid growth of high-technology firms. Hall (1992, 2002) and Brown et al. (2009) show that R&D intensive firms make little use of debt finance in the US. Brown et al. (2009), using data for publicly listed US firms from 1990 to mid-2000s, find that the stock market boom in the US over 1990s drove the R&D boom, especially in young and small firms. They conclude that the boom in external equity financing relaxed financial constraints on debt financing for high-technology firms and help them to finance their R&D projects. Rather they raise capital from the stock market. Using publicly-listed firms in the US, Chang and Song (2014) have a similar finding that firms that increase R&D investment tend to rely less on debt financing and reduce their leverage. All these evidence points to that stock market acts as a critical cog in productivity and economic growth through R&D investment channel. In the light of these existing evidence, a negative shock to stock market during a financial crisis may explain the decline in firms' R&D investment to a significant extent. Hence, it may be responsible for the sluggish productivity growth, and hence a persistent decline in economic growth following a financial crisis.

In this study, I focus on the effect of a negative shock in stock markets, namely GFC, on productivity growth via R&D investment channel. To the best of my knowledge, this is the first paper explaining the impact of financial crises on the decline in R&D investment and productivity growth by focusing on the stock market side. The analysis in this paper relies on the fact that the negative financial shock during the GFC following the collapse of Lehman Brothers in 2008 was largely unforeseen. I use cross-country industry-level data for manufacturing sectors of 17 European economies between 2003-2012. I start by showing several stylized facts on stock markets and R&D investment during and following the GFC in Europe. First, I illustrate that the stock market size (relative to the banking) varied substantially across European countries in the precrisis period. Hence, considering the existing evidence on the relationship between stock market development and R&D investment, it can be expected that a financial shock may have different implications across countries. Second, I illustrate that industries had lower leverage in the precrisis period in countries with larger stock markets, compared to other countries. This points to that, industries raised funding more from external equity financing than credit, especially in countries with larger stock markets. Third, I show that R&D investment across countries showed similar trends in the precrisis period, whereas R&D investment in countries with larger stock markets declined more following the GFC. This implies that the negative shock to the stock market played a key role in the decline in R&D investment in the aftermath of the GFC. Finally, I observe that industries with low precrisis leverage had similar trends in R&D investment before the GFC, however, in the aftermath of the GFC, those industries experienced a larger decline in R&D investment in countries with larger precrisis stock markets. I conclude that the third stylized fact was mainly driven by these industries with low leverage which were supposed to be more dependent on external equity financing than credit.

Having established these four stylized facts, I test stock market implications of the GFC in a formal setup. Given the fact that the negative financial shock during the GFC following the collapse of Lehman Brothers in the september of 2008 was largely unforeseen, the empirical strategy aims to identify the effect of a negative shock to the stock market on R&D investment. To mitigate concerns about reverse causality, I use industry-level and country-level variables from the precrisis period, and explore their role in the postcrisis decline in industry-level R&D investment and productivity growth. I find that R&D investment in industries with low precrisis leverage decreased more in the postcrisis period, especially in countries with larger precrisis stock market influence. The estimated coefficients are around one third of the average postcrisis R&D investment. Once I test this relationship for the productivity growth, I observe a similar result with a significant and large effect. Next, I ask whether this channel is specific to R&D investment. In line with the reasoning that R&D investment is more reliant on external equity financing, I find that the effect is much less significant in the case of non-R&D investment. Thus, I conclude that whereas the negative shock to the stock markets during the GFC affected R&D

investment substantially, it did not have such a significant effect on other types of investment. This emphasizes the role of the stock market in explaining the sluggish productivity growth, and hence economic growth, in the postcrisis period, through its role in the decline in R&D investment.

Demand shocks are absorbed at a granular level by appropriate fixed effects in the empirical analysis. Hence, changes in the demand that are specific to an industry are not likely to generate a bias in the result. Moreover, any potential bias arising from country-specific policies (e.g. subsidies, tax policies, structural reforms), or aggregate risks (e.g. sovereign risk), are absorbed using appropriate fixed effects. Assuming that the GFC was unpredicted, industry-level pre-existing conditions were not likely to be correlated with precrisis unobserved features that can correlate with the industry's postcrisis dynamics. The causal interpretation of the result relies on two further points. First, I document that industries with low precrisis leverage did not differ in terms of R&D investment trends in the precrisis period in countries with low versus high stock market influence (the fourth stylized fact above). Hence, the concern that low leverage industries have been experiencing different trends in R&D investment in different sets of countries in the precrisis period is ruled out. Second, I employ a placebo test using the 2001 recession, and observe that the relationship between pre-existing leverage and postcrisis R&D investment is not highly significant. This emphasizes the importance of the financial crisis component of the GFC rather than the accompanying recession. Furthermore, I employ a set of robustness checks alleviating other potential concerns.

In order to further test the role of stock markets on R&D investment following the GFC, I also adopt an alternative identification similar to Rajan and Zingales (1998). I show that industries that were dependent more on external equity financing (to fund their R&D investment) in the precrisis period experienced a larger decline in R&D investment and productivity growth in the postcrisis period, especially in countries with larger precrisis stock market influence. This finding supports the previous finding that industries that relied more on external equity financing to finance their R&D projects cut back more in R&D expenditures, especially in countries with larger precrisis stock market influence.

Until this point, I find that a negative shock to the stock markets had a negative impact on R&D investment and productivity growth in the aftermath of the GFC. However, it only captures the average effect. Hence, a relevant concern is whether this result arises largely from the initial large drop during 2008-2009, rather than a persistent effect during the period of 2008-2012. So, I ask whether the effects are persistent, rather than capturing only the initial drop. This is a crucial point, since the GFC had a persistent negative impact on economic growth. I note that even a transitory impact on R&D investment may still have a persistent impact on economic growth through lower productivity growth. However, a more persistent negative impact of R&D investment generates a deeper loss in economic growth, via losses in productivity growth. In order to test this, I use dynamic regressions. I show that the impact is highly persistent and statistically significant for all years in the aftermath of the GFC, even five years after the event. This emphasizes that policies that address stock markets and the drop in R&D investment would play a crucial role for economies to recover from a financial crisis.

1.1.1 Related literature

This paper first contributes to the literature on the negative effects on financial crises on economic growth with a specific focus on R&D investment and productivity growth. Long-lasting effects of financial crises for different sets of countries are documented by several studies, e.g. Cerra and Saxena 2005 and 2008, Reinhart and Rogoff 2009, Furceri and Zdzienicka 2011, Teuling and Zubanov 2014, pointing to productivity losses. Several recent papers make an attempt to identify the channels through which financial crises give rise to productivity loss. Specifically, they focus on the innovation channel whereby financial crises affect firm investment in productivity-enhancing activities -such as those lead to patents-. For instance, using industry-level data from a large sample of advanced and emerging market economies over four decades, Hardy and Sever (2018) find that banking crises lead to a large and persistent decline in both quality and quantity of patents -the output of innovative activity-. Nanda and Nicholas (2014) focus on the firms in the US and show that there is a negative relationship between bank distress and the level, quality and trajectory of firm-level innovation during the Great Depression. Ates and Saffie (2013) propose a model and use Chilean plant-level data and show that output losses following a financial crisis can be explained by permanent productivity losses. I contribute to this strand of the literature by empirically focusing on the role of stock market in explaining the R&D and productivity growth channel of economic losses following a financial crisis.

More specifically, this paper adds to a few recent papers focusing on the channels through which the GFC could lead to productivity losses in Europe and other advanced economies. Using a sample dominated by European economies, Duval et al. (2017) show that firms with high pre-existing leverage experienced lower TFP growth. They discuss that high pre-existing leverage leads to financial frictions (e.g. debt overhang problem or roll-over risk) following a tightening in credit conditions in the aftermath of the GFC. In a similar set of countries, Ahn et al. (2018) find that firms with high pre-existing leverage cut back more on intangible investment in the postcrisis period, particularly whenever high degree of competition prevented them from self-financing. Considering the role of intangible investment on productivity, this finding suggests that one channel for productivity decline in previously highly levered firms may be the decline in productive investment, especially when firms cannot self-finance such investment projects. Kalemli-Ozcan et al. (2018) find that the decline in investment -a possible source of lower productivity- in the Euro Area in the aftermath of the GFC was related to high leverage, increased debt service, and having a relationship with a weak bank. All these studies focus only on the role of the banking shock and investigate the effect of high pre-existing leverage (or balance sheet vulnerabilities) in the decline in productivity growth and different sorts of investment. On the other side, there is no study focusing on the stock market side, although it is particularly important in the case of R&D investment and hence productivity growth, as discussed above. The main contribution of this study is to show that the negative shock to stock markets have also played a key role in the decline in R&D investment, and hence aggregate productivity growth, in advanced economies in the aftermath of the GFC.

The rest of this paper is organized as follows. Section 1.2 describes the data. Section 1.3 illustrates four stylized facts. Section 1.4 introduces the baseline empirical approach and results. Section 1.5 introduces the an alternative empirical approach and results. Section 1.6 explores the dynamic effects. Section 1.7 shows that empirical findings are robust to different tests. Section 1.8 concludes.

1.2 Description of the data

In this study, I use data at both country- and industry-levels. The industry-level data is mainly from EU-KLEMS database.[1] The database has information on gross output, value-added, wage, number of employees and capital formation. Moreover, it has information on TFP (value-added based) and capital investment in R&D. I use data from manufacturing industries in 17 European countries between 2003-2012. In the KLEMS database, the manufacturing sector is divided into 11 subsectors. The reason for having 11 subsectors in the manufacturing is that

[1] It is available at www.euklems.net.

the database merges several 2-digit industries in the NACE (Revision 1) classification codes into one industry, due to reasons related to data availability. Hence, an industry in EU-KLEMS refers to a 2-digit or a broader industry in NACE classification. Industries in EU-KLEMS are illustrated in Appendix. I followed the procedure described by O'Mahony and Timmer (2009) to match industries from ORBIS-AMADEUS, Compustat North America and EU-KLEMS databases.[2] For a more detailed overview of the the EU-KLEMS database, see O'Mahony and Timmer (2009), van Ark and Jager (2017) and Jager (2017).

In this study, I focus on industry-level R&D investment and productivity (TFP) growth. Hence, the dependent variables in the empirical tests are either R&D investment and TFP growth (value-added based) in different analyses. The KLEMS database obtains data on R&D investment from OECD Research and Development in Industry Database. It follows a methodology using price indexes to create a data which is comparable across countries and time. I use percentage investment in R&D projects. It is the difference in R&D capital stock divided by lagged total fixed assets. In order to calculate TFP growth, the KLEMS growth accounts rely on the growth accounting methodology by Jorgenson and Griliches (1967), Jorgenson, Gollop and Fraumeni (1987) and Jorgenson et al. (2005), under the assumptions of competitive factor markets, full input utilization and constant returns to scale. Once accounting for growth rates of intermediate inputs using av-

[2] I use the correspondence tables available at unstats.un.org/unsd/classifications/econ. I first matched industries in EU-KLEMS database with industries in Compustat. Also, I matched KLEMS industries with industries in the ORBIS-AMADEUS database.

erage input shares, capital and labor, it extracts TFP growth as the residual. I use percentage change in TFP as TFP growth.

The main reason to use R&D investment is its well-established link with productivity.[3] However, I note that R&D investment is the input for innovation, whereas patents is the output. In the KLEMS-Linked database, industry-level patent data is available only from 1980-2003 though. Given my focus on 2003-2012 period, I need to focus on R&D investment in this project, as a proxy for innovation. Once I use the data in the period where both R&D investment and patents are available (i.e. 1980-2003), I observe that industries that invested more in R&D during this period were industries which issued larger number of patents. The cross-section correlation between number of industry patents and R&D investment is large (0.88 on average) and relatively stable over time (see Appendix for details). Moreover, the cross-section correlation between average number of patents over 1980-2003 and R&D investment in the precrisis period (i.e. over 2003-2007) is around 0.80. Hence, although R&D investment is the input for innovation, I have evidence that this is highly related to the output (patents) in European countries in the sample.

In an alternative specification, I construct industry's dependence on exter-

[3] A recent study on this relationship is by Doraszelski and Jaumandreu (2013) who provide both a theoretical background for a novel estimation strategy and empirical evidence. For a detailed econometric analysis on the relationship between R&D and productivity, see Griliches (2007). Among others, see Gilchrist (1998), Wieser (2005) for detailed surveys on the existing evidence on the positive link between R&D expenditures and TFP from different countries at country-, industry- and firm-levels.

nal equity finance to fund its R&D investment. I use Compustat North America firm-level data for the large-listed US firms during the precrisis period and follow Rajan and Zingales (1998) to construct this measure. I identify an industry's need for external equity finance for R&D investment as the ratio of the net amount of equity issues to R&D expenditures. Moreover, using the same data, I identify high-technology industries based on their R&D investment (normalized by total assets) in the precrisis period.

The KLEMS database misses industry-level financial variables. This is why I construct industry-level leverage using ORBIS-AMADEUS database. The database is constructed by the Bureau van Dijk Electronic Publishing (BvD). Administrative data at the firm level are first collected by local Chambers of Commerce and, then, relayed to BvD through roughly 40 different information providers including business registers. Given my focus on Europe, I also use the AMADEUS database which is the European subset of ORBIS database. AMAEDUS has an advantage that company reporting is regulatory even for small private firms. As a result, the ORBIS-AMADEUS database is representative in terms of overall value-added and output and distribution of firm size, especially for manufacturing industries in countries in the sample over the sample period. For more details on the data collection and cleaning procedures, I refer to Gopinath et al. (2017) and Kalemli-Ozcan et al. (2015). Industry-level leverage is aggregate from the firm-level data by financial debt over fixed assets. I use the precrisis (2003-2007) average of this variable.

Aggregate variables are from World Banks World Development indicators. I use stock market capitalization (in percentage of GDP) to proxy for stock market development. In a robustness check, I also use value of stocks traded for this purpose. For banking development, I use banking credit to nonfinancial private debt as percentage of GDP. I define precrisis stock market development relative to the banking as the ratio of the two measures. In robustness checks, I also control for trade openness, defined as exports plus imports as a share of GDP, and total financial development, defined as stock market development plus banking credit as a share of GDP.

1.3 Stylized facts

A. Precrisis stock market influence in countries

I start by showing whether there is a considerable variation across 17 countries in terms of stock market influence relative to the banking in their financial markets in the precrisis period. In each country, I take average ratio of the stock market capitalization to the banking credit to nonfinancial private sector over the period 2003-2007.

Figure 1.1 illustrates the average precrisis ratio of stock market capitalization to the banking credit to nonfinancial private sector in each country over the period 2003-2007. It shows that there is a significant variation in terms of stock market development in the precrisis period (relative to the banking development) across countries. This allows me to investigate whether countries with larger dependence on stock market had different implications in terms of R&D investment and productivity in the postcrisis period.

I include the US in Figure 1.1 to provide a comparison between the US and Europe. As can be seen, the US relied much more on stock market than banking credit in the precrisis period compared to all countries in Europe. However, countries like Finland, Poland, Belgium and France had larger stock markets than the size of banking credit over the precrisis period, i.e. the ratio is greater than 1 for these countries. On the other hand, in countries such as Germany, Ireland, Austria, Denmark, Portugal, Slovakia, the size of stock market was smaller than the half of the banking credit (i.e. the ratio is smaller than 0.5). For the rest of the analysis, I categorize countries based on the degree of stock market influence in the precrisis period relative to the banking. I identify countries as high precrisis stock market influence, if this ratio is above the median across countries. In other words, Finland, Poland, Belgium, France, Czechia, Netherlands, Slovenia and Spain are called as countries with high precrisis stock market influence, compared to the rest of the countries in the sample. The rest is called as countries with low precrisis stock market influence.

B. Precrisis leverage in industries

Second, I investigate the relationship between precrisis leverage at industry-level and precrisis stock market influence at country-level. It can be expected that industries in countries with higher stock market influence in the precrisis period may have lower leverage, since they may rely more on external equity financing. To investigate this sort of relationship, for each industry, I compare precrisis leverage in countries with higher precrisis stock market reliance to that of leverage in countries with lower stock market reliance.

In each industry, I find the average leverage in the precrisis period in countries with high and low precrisis stock market influence. Then, I take the ratio of the precrisis industry leverage in countries with high precrisis stock market influence to the precrisis industry leverage in countries with smaller precrisis stock markets. Hence, whenever this ratio is smaller than 1, it means that precrisis leverage was lower in that industry in countries with high precrisis stock market influence relative to the countries with low precrisis stock market influence. For such industries with the ratio smaller than 1, it means that larger stock markets were related to lower industry leverage in the precrisis period. In other words, it points to that industries had lower precrisis leverage in countries with larger stock markets.

Figure 1.2 illustrates average precrisis leverage in industries in countries with high precrisis stock market influence relative to the leverage in same industries in the rest of the countries. The ratio is smaller than 1 for all manufacturing sectors -except wood-, which means that precrisis leverage in the corresponding industry was lower in countries that are relatively more reliant on stock market (relative to the banking) in the precrisis period. I conclude that, in general, industries relied less on banking in countries with more developed stock markets in the precrisis period.[4]

C. Aggregate manufacturing R&D investment in countries

Third, I investigate whether R&D investment in manufacturing sector on aggregate was affected differently following the GFC in countries with high versus low precrisis stock market influence. If larger stock markets were specifically related to financing R&D projects in the precrisis period, it could be expected that R&D investment may decrease more in countries with a larger precrisis stock market influence in the aftermath of the GFC.

Figure 1.3 shows that R&D investment rates in the precrisis period followed similar trends in manufacturing sectors of countries with high versus low precrisis stock market influence. However, in 2008, R&D investment in manufacturing dropped around 2.1 percentage points in countries with high precrisis stock market influence. On the other side, it dropped around 1.2 percentage point in countries with lower precrisis stock market influence. Moreover, while R&D investment ap-

[4] I also note that new debt issuance and new external equity issuance are negatively correlated in 14 countries in the sample in the precrisis period.

proached to precrisis level more quickly in countries with low stock market influence, the postcrisis investment rate stayed much lower in countries with large stock markets. I conclude that manufacturing industries in countries with larger precrisis stock markets have cut back more in R&D investment following the GFC. Hence, Figure 1.3 further motivates the idea that the role of stock markets during a financial crisis is crucial in explaining the decline in R&D investment and hence productivity growth. Finally, I observe that R&D investment in the precrisis period was higher in countries with high stock market influence - which is in line with the existing evidence in the literature on the positive relationship between stock market evelopment and R&D investment (e.g. Brown et al. 2009).

D. R&D investment in low leverage industries

Given the fact in Figure 1.3 that R&D investment in manufacturing sectors in countries with high precrisis stock market reliance decreased more than other countries, I finally explore whether this difference is related to the decrease in R&D investment in industries with low precrisis leverage. That is, if industries with lower leverage was more reliant on stock market in the precrisis period, their R&D investment would decrease more following a negative financial shock.

Figure 1.4 illustrates that R&D investment in industries with low leverage was similar in countries with both high and low precrisis stock market influence in the precrisis period. However, R&D investment in those industries decreased sharply (2.3 percentage points) in countries with larger stock markets, compared to the drop in industries in countries with low stock markets (0.4 percentage points). This points to that, in countries with larger precrisis stock market influence (relative to the banking), industries that had lower leverage (and potentially larger dependence on external equity financing) were affected more by the negative financial shock of 2008. Moreover, the decline in R&D investment in countries with larger precrisis stock market influence (as shown by Figure 1.3) was mainly driven by the decline in R&D investment in industries with lower precrisis leverage following the GFC. Finally, the fact that industries with low leverage invested more in R&D in countries with larger stock market influence in the precrisis period is line with the existing evidence in the literature on the relationship between external equity financing and R&D investment. Having established these stylized facts, I now test the relationship in a regression set-up.[5]

1.4 Empirical approach

Now, I test the relationship between pre-existing stock market influence in a country and the drop in R&D investment in industries with low precrisis leverage a formal setup to make causal inference. The baseline analysis is based on a difference-in-differences panel specification that compares the change in R&D in-

[5] I provide three different variation of this graph in Appendix to illustrate that the gap in R&D investment of low leverage industries was the most striking result.

vestment between industries that entered the crisis with high versus low leverage in countries that had high versus low stock market influence (relative to the banking), before and after the GFC. The precrisis period is defined as 2003-2007, whereas the postcrisis period is 2008-2012, following recent studies (Ahn et al. 2018, Kalemli-Ozcan et al. 2018, Duval et al. 2017). The dependent variable is the annual R&D investment at the industry-level. To mitigate concerns about reverse causality, I use explanatory variables at both country- and industry-levels from the precrisis period. The main explanatory variable of interest is the triple interaction of precrisis leverage of the industry, precrisis stock market dependence in the country and the postcrisis period. An important underlying assumption for the difference-in-differences strategy is that there are similar R&D investment trends in the precrisis period in industries with low precrisis leverage across countries with high versus low precrisis stock market influence, together with a divergence in the trends in the postcrisis period. Figure 1.4 justifies this assumption. I also control for lagged value industry leverage to account for postcrisis dynamics in leverage. Moreover, I control for the lagged value-added share of industry, since larger industries may have been influenced by other factors relative to smaller industries. The specification is as follows:

$$\Delta Y_{j,c,t} = \alpha_1 Precrisis\ Low\ Leverage_{j,c} \times Post_t$$

$$+\alpha_2 Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$$

$$+\gamma \mathbf{X_{j,c,t}} + \theta_{j,c} + \theta_{j,t} + \theta_{c,t} + e_{j,c,t} \tag{1.1}$$

where j is 2-digit sector, c is country and t is year. The dependent variable $\Delta Y_{j,c,t}$ is the growth rate of one of the following variables: (i) R&D investment and (ii) TFP growth in different regressions. $Precrisis\ Low\ Leverage_{j,c}$ is a dummy which takes 1, if a sector's leverage is (on average) below the median leverage in that county in the precrisis period. Hence, it identifies industries that are likely to be more dependent on external equity financing than banking credit, compared to the rest of the industries within a country. As a result, it allows me to compare industries within each country.[6] $Precrisis\ Stock\ Market_c$ is a dummy based on the influence of stock market (relative to the banking sector) in a country's financial system in the precrisis period. The variable $Precrisis\ Stock\ Market_c$ is assigned to be 1 in countries that are above the median value of the ratio is Figure 1.1 (i.e. Finland, Poland, Belgium, France, Czechia, Netherlands, Slovenia, Spain); and 0 otherwise. I call these 8 countries with $Precrisis\ Stock\ Market_c = 1$ as countries with high precrisis stock market influence. $Post_t$ is a dummy which is 1 in 2008 and afterwards, denoting the postcrisis period. $\mathbf{X_{j,c,t}}$ include control variables that can vary at country-industry-year level and potentially affect results, namely lagged values of value-added share and leverage. Standard errors are clustered at country-industry level. Finally, $\theta_{j,c}, \theta_{j,t}$ and $\theta_{c,t}$ are industry-country, industry-year and country-year fixed effects, respectively.

Three sets of fixed effects are crucial for the identification. First, some indus-

[6] One reason why I prefer a dummy for industry leverage is that it is constructed from another dataset (ORBIS-AMADEUS) with a majority of small and medium-sized firms. Using a dummy, I alleviate concerns about this and simply group industries. However, if I use a continuous variable, I get qualitatively similar results with lower coefficient estimates.

tries may be more dependent on external finance for inherent (e.g. technological) reasons (Rajan and Zingales 1998). Those industries would be more affected by a negative financial shock, solely due to technological reasons. Thus, controlling for all unobservable features or shocks that are specific to an industry (j) is crucial. However, these industry-specific factors can vary based on the country and year. For instance, if the demand for the textiles in a country decreased more than the demand for other industries in the same country, or more than the same industry in other countries, this would generate a bias in the result. In addition, if the demand for textiles in all countries decrease during in some years more than other sectors, this would yield an additional bias in results. Second, there are country-specific factors, e.g. changes in aggregate demand or sovereign risks whose effects can vary through years, as well as sectors in a given country. Other examples which are needed to absorbed can be local credit shocks, subsidies, tax policies or structural reforms affecting specific industries in specific countries. Including three sets of fixed effects at country-industry ($\theta_{j,c}$), industry-year ($\theta_{j,t}$) and country-year levels ($\theta_{c,t}$) rule out any bias arising from such factors.

If the postcrisis R&D investment in industries with low precrisis leverage decreased more, especially in countries with larger stock market reliance in the precrisis period, I expect α_2 to be negative.

1.4.1 Results

This section illustrates the results from the specification in (1.1). Column 1 in Table 1.1 shows that industries that had low leverage in the precrisis period did not significantly cut R&D investment in the postcrisis period (α_1 is statistically insignificant). However, in countries that were more reliant on stock markets, R&D investment in those industries decreased (0.33 percentage points annually) in the postcrisis period. Comparing the average annual growth rate in R&D investment in manufacturing sectors in those countries (with large stock market reliance) the postcrisis period (0.61 percentage points), the result suggests that this channel is economically large.

I follow a counterfactual exercise to evaluate aggregate implications of the estimated result in Column 1. First, I calculate the share of each industry's R&D investment in aggregate manufacturing R&D expenditure in the precrisis period in each country. Second, I calculate the share of each country's manufacturing R&D investment in aggregate manufacturing R&D investment in the precrisis period in the sample. Third, I assume that (i) the effect is -0.33 percentage point for low leverage industries in countries with ihgh stock market influence, and (ii) effect is zero for the rest of the industries. This exercise suggests that R&D investment in the postcrisis period was dampened by 19 percent. In other words, it could have been $(1 + 0.19) \times 0.61 = 0.72$ percentage points in the postcrisis period, instead of 0.61.

The second column tests the relationship for TFP growth. If the hypothesis discussed above is right, R&D investment must provide a channel through which TFP has decreased, and hence a similar effect must be observed for TFP. Column 2 illustrates a similar finding for TFP growth (0.2 percentage points lower annually). Hence, I conclude that industries that raised funding more from stock markets in the precrisis period had to cut back their R&D investment more, and hence experienced lower productivity growth, following the negative financial shock, especially in countries with larger stock markets in the precrisis period. When I follow the previous counterfactual exercise for TFP growth, the postcrisis average TFP growth would have been 0.24 percentage point, instead of 0.21.

In order to correct for utilization, I follow an exercise inspired by Basu et al. (2006). More specifically, I follow and refer to Levchenko and Pandalai-Nayar (2015). I generate utilization-adjusted TFP series using data on capital stock and labor compensation at industry-level. In the production function, I assume that capital share is 0.35 following Gopinath et al. (2017). I note that even though this share may change based on country or industry level, it is not important in terms of my results, since corresponding fixed effects absorb the potential bias from such regularities. This exercise has less data points due to data limitation on either capital of labor in KLEMS dataset. When I generate the utilization-adjusted TFP series, the estimated coefficient turns out to be -0.099, instead of-0.196. It is significant at 5 percent level. Hence, although the size of the effect is smaller, the result stays similar and still significant. I conclude that the result represented in column 2 is not driven by the changes in utilization of inputs in the postcrisis period.

1.4.2 Is the result specific to R&D investment?

Given the findings in Column 1 of Table 1.1, I now investigate whether this is specific to R&D investment. As mentioned before, using data from similar sets of countries, recent studies showed that all sorts of investment has declined in the postcrisis period. However, if industries with low pre-existing leverage did rely more on the stock market, especially in financing their R&D investment, it is expected that the effect on non-R&D investment would be less important. I replace the dependent variable in specification (1.1) by non-R&D investment and run the same regression. Table 1.2 illustrates that the impact is significant only at 10 percent level. This suggests that the previous finding is somewhat specific to R&D financing. Hence, it points to that a negative financial shock to stock markets drive a decline in productivity, specifically through its negative impact of the RD investment.

1.4.3 Extending the analysis to all sectors

One reason why I restrict the analysis to manufacturing sectors is that capital series and hence TFP is harder to measure for other sectors compared to the manufacturing (Gopinath et al. 2017). Another reason is that KLEMS database does not have detailed sector classification for other industries. Manufacturing sectors in these countries is large and contribute to approximately one third of aggregate value-added on average. However, it may still be sensible to check whether results stay similar when the analysis is extended to the entire set of sectors that we have data. I run the regression in the specification in (1.1) using all available sectors in KLEMS database, except mining, agricultural and financial sectors. I drop mining and agricultural to eliminate a potential bias arising from natural resources. I note that the data is unbalanced in this analysis, with missing sectors or years across countries.

Table 1.3 illustrate the results for the entire set of sectors in the economy. I observe that the results stay qualitatively similar, although the coefficient estimates for both R&D investment and TFP growth in Column 1 and 2, respectively, are smaller than the estimated result for the manufacturing sectors.

1.5 Alternative approach

The underlying assumption in the specification in (1.1) is that industries with low precrisis leverage were dependent more in stock markets, and hence they were affected by the GFC more in countries with larger stock markets. In order to further test this, I now adopt a different identification strategy which is similar to Rajan and Zingales (1998). I replace country-industry level precrisis leverage with industry-level proxy for stock market dependence specifically for financing R&D investment.

I calculate stock market dependence at industry level following Rajan and Zingales (1998), using data for the large-listed US firms from Compustat. I identify an industry's need for external equity finance for R&D investment (defined as the ratio of the net amount of new equity issues to R&D expenditures). There are two underlying assumptions in this specification. First, the assumption that capital markets in the US -particularly for the large-listed firms- are relatively frictionless in the precrisis period allows me to identify an industry's technological demand for stock market financing for its R&D investment. Second, the assumption that such a technological difference carries over to other countries, I test whether industries that are more dependent on stock market financing for their R&D projects get affected more by a financial shock, especially in countries with relatively larger stock market influence.

This would imply that an industry such as machinery which requires larger external equity funding for R&D investment should be affected more by a negative financial shock than wood industry, that requires little external equity financing, in countries that were more reliant on stock market financing.

To construct the dummy variable for the dependence on external equity finance for R&D investment, I first calculate the ratio of the net amount of equity issues to R&D expenditures for each firms in Compustat for years 2003-2007. Then, in each industry, I take the median value of this ratio in each year. Finally, in each country, I divide industries based on their stock market dependence using the median of this value across industries. I costruct a dummy variable which takes 1, if an industry is above the median of stock market dependence based on this measure. I expect that industries that are relatively more dependent on stock market for their R&D projects would be affected more in countries with larger stock markets (relative to the banking) in the precrisis period. The specification is as follows:

$$\begin{aligned}\Delta Y_{j,c,t} &= \beta_1 Precrisis\ Stock\ Dependence_j \times Post_t \times Precrisis\ Stock\ Market_c \\ &\quad + \gamma \mathbf{X_{j,c,t}} + \theta_{j,c} + \theta_{j,t} + \theta_{c,t} + e_{j,c,t} \qquad (1.2)\end{aligned}$$

Precrisis Stock Dependence$_j$ is the dummy which takes 1, if a sector's stock market dependence for financing R&D investments is above the median. I expect β_1 to be negative.

Second, I check the following. As mentioned above, there is plenty of evidence that industries that rely more on stock market invests R&D projects more heavily than others. So, if this is the case, the mechanism proposed in previous tests must work through high-technology industries as well, since high-technology industries are likely to be more reliant on external equity financing. In a separate test, I replace industry-level stock market dependence dummy with industry level high-technology dummy. I construct this variable similarly by using the Compustat data. For industries that invest more in R&D projects in the precrisis period are identified as high-technology industries.

1.5.1 Results from the alternative approach

In this section, I illustrate results from the alternative specification in (1.2). Column 1 in Table 1.4 shows that R&D investment in industries that are more reliant on stock market decreased around 0.39 percentage point annually in the postcrisis period in countries that were more reliant on stock market in the precrisis period. Column 2 shows a similar finding for the TFP. Hence, I conclude that results are in line with the baseline findings.[7]

Table 1.5 illustrates the results when I use high-technology dummy, instead of a dummy for high dependence on external equity financing. The results stay almost the same. The reason for this is that industries that are categorized as high-technology (chemicals, transportation, electrical devices, machinery, others) are almost the same industries with high dependence on external equity finance (chemicals, transportation, electrical devices, machinery, wood).

1.6 Dynamics effects

So far, I have analyzed the role of stock market on the average R&D investment and productivity growth in the postcrisis period. As a result, the estimates reflect

[7]In a separate test, I use country-industry level dependence on external equity financing (to fund R&D in the precrisis period) by using data from listed firms in each country from Worldscope database. Results are qualitatively similar. However, there are two concerns about this approach. First, some countries have very limited number of firms in Worldscope database. Second, this approach can generate endogeneity.

average effect over the period 2008-2012. In this section, I investigate the dynamic response of R&D investment and productivity growth to show that estimated effects do not just reflect transitory responses only in the early years of the postcrisis period, but instead are persistent. For this purpose, I modify the specification in 1.1, using dynamic regressions. The specification is a cross-country cross-industry regression and is as follows:

$$\begin{aligned} \Delta Y_{j,c}^{pre-t} &= \kappa_t Precrisis\ Low\ Leverage_{j,c} \times Precrisis\ Stock\ Market_c \\ &+ \gamma \mathbf{X_{j,c}} + \theta_j + \theta_c + e_{j,c} \end{aligned} \tag{1.3}$$

where $Y_{j,c}^{pre-t}$ is the change in Y from the precrisis average to the postcrisis year t with $t = 2008, ..., 2012$ in different regressions. Hence, this set-up is able to capture dynamic effects for each year in the postcrisis period, separately. For instance, for $t = 2008$, it captures the effect of effect of the GFC on R&D investment of low leverage industries in countries with higher stock market influence only for 2008. When $t = 2009$, it captures the effect in 2009, and so on. Thus, the purpose of this specification is to investigate the persistent of the effect over the postcrisis years from 2008 to 2012. The dynamic effect in year t will be captured by the coefficient estimate κ_t for that year. I include both industry-level and country level fixed effects, θ_j and θ_c, to absorb any biases potentially arising from country-specific and industry-specific factors. If the effect is persistent, I expect κ_t to be negative and statistically significant for most of the years in 2008 and afterwards.

1.6.1 Results on dynamics effects

I run the regression in specification (1.5) for each year, and separately for R&D investment and TFP growth. I draw the estimates for κ_t for $t = 2008, ..., 2012$ in Figure (1.5) with 90 percent confidence interval. Figure 1.5 illustrates the results from the specification 1.3 for the R&D investment and TFP growth in two panels.

The left panel of Figure 1.5 shows the response on postcrisis R&D investment in industries with lower precrisis leverage in countries with larger pre-existing stock makret influence, compared to the precrisis period. The point estimate is always lower than zero together with confidence intervals being below zero. This means that the effect is persistent over the postcrisis years and statistically significant. The point estimate predicts 0.1 percentage point decline in the R&D investment in 2008, which is smaller than the estimates in the following year. This is partly reflecting that the collapse of Lehman Brothers took place in September 2008. In years 2009 and 2010, the drop in R&D investment is predicted to be around 0.45 percentage points. As the time period extended to 2011 and 2012, the estimated effect gets slightly lower, but not approaching to zero. The predicted effect is still statistically and economically significant (around 0.25 percentage points) even in 2012. Hence, I conclude that there is no evidence of a strong recovery from the GFC in terms of R&D investment even 5 years after the event. This implies that

R&D projects have not simply been postponed following 2008, but likely to be canceled. This points to persistent losses in productivity growth in the postcrisis period. This is what the right panel of Figure 1.5 tests by using specification (1.3). It shows a similar evidence that productivity growth in industries with lower pre-existing leverage has been persistently lower in the postcrisis period, especially in countries with larger precrisis stock market influence. In year 2008, the effect of TFP is small and statistically not significant. This can reflect that the decline in R&D investment shows up in TFP growth with a delay. Consistent with this, the largest effect on TFP growth is observed one year later in 2009. It is statistically and economically significant, around 0.24 percentage points. From 2010 to 2012, the effect of TFP growth is still large and significant. I conclude that the effect on TFP growth is highly persistent with little evidence on recovery. These findings suggest that the persistent negative effect of financial crisis on economic growth can be explained to some extent through R&D investment and productivity growth channel by focusing on the stock market side.

1.7 Robustness checks

I now aim to address several potential concerns about the results from the specification (1.1) in Table 1.6. First, I employ a placebo test to observe the role of the financial crisis component of the GFC, rather than capturing the accompanying recession. This test alleviates the concern whether the findings may purely arise from the recession following the GFC, and thus is crucial for the identification of the financial channel in the result. In the first column of Table 1.6 in Panel A, I employ a placebo test using 2001 as the year of the crisis, since it was the start of recession for the most of the countries in the sample. The precrisis (postcrisis) period is defined as 1999-2000 (2001-2002). Result is statistically insignificant, emphasizing the role of the financial crisis component of the GFC, rather than the accompanying recession. This helps me to identify the financial channel that could give rise to the decline in R&D investment and productivity growth.

Second, I focus more directly on the GFC in a narrower time window (2005-2010) to isolate the period of partial recovery following 2010 illustrated in Figure 1.3 and Figure 1.4. More importantly, this test also addresses potential concerns about the 2011-2012 period in which sovereign debt crisis erupted, and the European Central Bank's Outright Monetary Transactions (OMT) program launched in 2012. Column 2 of Table 1.6 in Panel A shows that results are qualitatively very similar to the baseline result with larger coefficient estimates.

Third, I use an alternative method to calculate precrisis industry-level leverage from the ORBIS data. In specification 1.1, I calculate leverage as the ratio of total financial debt to total fixed assets at industry level, aggregated over firms in each industry. One concern about this may be that a few firms in an industry with either high fixed assets or high debt may influence the industry level leverage. To check this, I use the median leverage across firms to get the industry-level leverage in each years over 2003-2007. Then, I take the average of these values to find the precrisis industry leverage. Finally, I assign a dummy for low leverage industries using this measure. The result is in Column 3 of Table 1.6 in Panel A. It is very similar to the baseline result.

Fourth, I change precrisis (2003-2007 average) leverage with the industry-level leverage in 2007, since this is the leverage level that an industry had just before the crisis. I note that since leverage is a very persistent process in the data, the dummy variable for leverage is almost not affected, with a few exceptions. Column 4 of Table 1.6 in Panel A. It is very similar to the baseline result.

Fifth, I use a different definition of the stock market dummy to see whether results are sensitive to the definition. As mentioned before, the stock market dummy was assigned 1 for the countries that were above the median of stock market influence (8 countries in the sample). Now, I check whether results change, if stock market dummy is assigned 1, only if stock market to the banking ratio is greater than 1 (rather than using the median value). There are 4 countries in Figure 1.1 with stock market capitalization being larger than banlking credit in the precrisis average (i.e. Finland, Poland, Belgium, France). Thus, the dummy for stock market development in this test identifies countries with larger stock markets than banking, instead of comparing relative influence of stock markets (relative to the banking) across countries. The last column in Panel A in Table 1.6 illustrates that results are qualitatively the same.

In Panel B of Table 1.6, I address the concern about country-level variables that can potentially influence the results. First, I use an a widely-used alternative proxy for stock market development. I adopt the value of stocks traded (instead of stock market capitalization) to proxy stock market development in the precrisis period. Column 1 shows that the result is almost the same. Second, I adress a potential concern for an omitted vairable, i.e. total financial development. I include a measure of financial development, calculated as stock market capitalization plus banking credit to nonfinancial private sector, in specification in (1.1). I interact it with both the postcrisis dummy, as well as precrisis low leverage and precrisis stock market dummies. Column 2 illustrates that the results does not change much. Similarly, I include a measure for trade openness, since different industries in a given country can get affected differently by the drop in international trade following the GFC, due to, for instance, the share of exports or imports in its activities. A proxy for trade openness is calculated as export plus imports as a percentage of GDP, in specification (1.1). The third column shows that it does not change the result.[8]

I also note that I employ all the robustness checks in this section for the productivity growth as well. Results are qualitatively similar and are illustrated in Appendix. I conclude that the previous results are not sensitive to these tests.

[8] I also note that the results are robust if I add aditional controls at country-yrar level, such as 10-year government bond spread.

1.8 Conclusion

Financial crises are associated with large and persistent output losses, pointing to productivity losses. A potential channel for this phenomenon is the decline in R&D investment following a financial crisis, since RD investment is a key driver of productivity growth. Considering existing evidence on that R&D investment is more dependent on stock market financing than banking credit, it is crucial to understand the role of the stock market following a financial crisis in the decline in productivity growth through R&D investment channel. To the best of my knowledge, there is a gap in the literature on the financial crises and economic growth in this sense. This paper fills this gap by focusing on the fact that productivity and economic growth in European economies decreased during the GFC and has remained sluggish ever since. I shed some light on the role of stock market in explaining the decline in productivity growth, through its impact on the R&D investment. I show that industries in countries with larger stock market influence have cut back more in R&D investment and experienced lower productivity growth in the postcrisis period. The estimated effect is economically significant and highly persistent. I note that findings in this paper do not rule out the role of the banking side, however, they suggest that policies that address stock market can also alleviate economic losses and facilitate recovery from a financial crisis.

Appendix

Patents and R&D investment over 1980-2003

I merge KLEMS-Linked data for industry-level patents and EU-KLEMS for R&D investment. Since the patent data is available only for 1980-2003, I restrict this analysis to this period. Figure 1.6 illustrates cross-section correlation between R&D investment and number of patents for manufacturing industries in 17 countries for each year over the period 1980-2003. Note that the data is unbalanced due to missing values. Note that I use R&D investment with 1-year lag due to potential lags between the actual investment and obtaining a patent. The mean value over this period is 0.88. Note that if R&D investment is used with 2-year lag, the mean value is around 0.89.

Manufacturing sectors in EU-KLEMS database

Table 1.7 shows 11 sectors in KLEMS database.

Variations of Figure 3

In Figure 1.4, I represent R&D investment in lowl everage industries in different sets of countries. In Figure 1.7, I illustrate R&D investment trends in different sets of industries in different sets of countries.

The panel on left top show that R&D investment trends in industries with high precrisis leverage did not differ much in the postcrsisi period across different countries. The panel on right top illustrates that R&D investment in different industries in countries with high stock market were not very different. Finally, the panel on the second row shows that R&D investment in high leverage industries decreased more than others in countris that relied more on banking.

Hence, I conclude that the striking gap in R&D investment of low leverage industries in countries with low versus high stock martket dependence, as illustrated in Figure 1.4 help to explain the gap in the postcrisis R&D investment in two sets of countries.

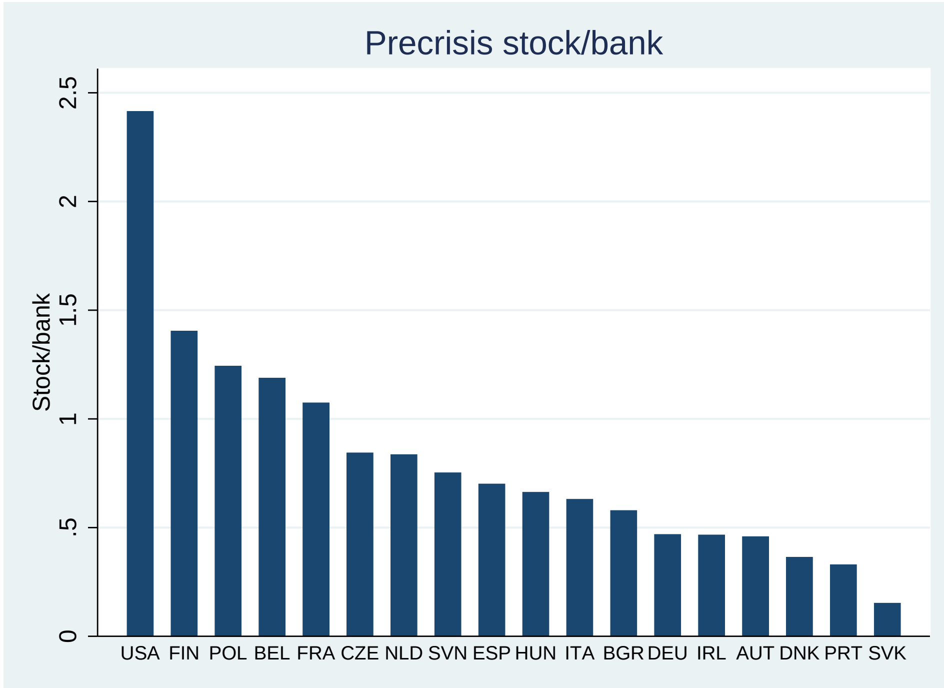

Figure 1.1: *Average precrisis ratio of stock market capitalization to the banking credit to nonfinancial private sector.*

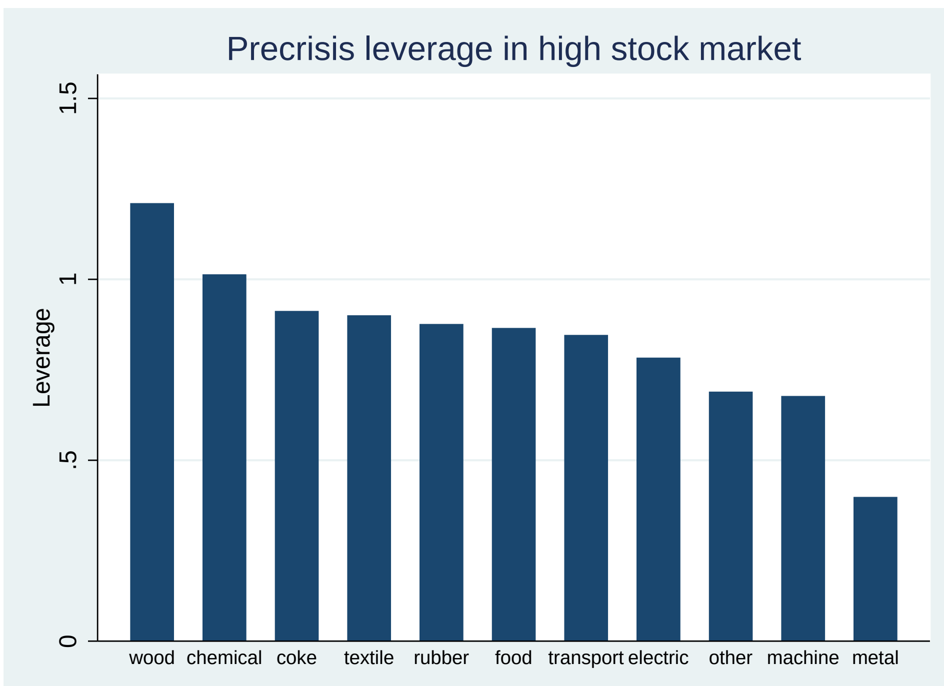

Figure 1.2: *Average precrisis leverage in industries in different categories of countries (based on stock market size relative to the banking)*

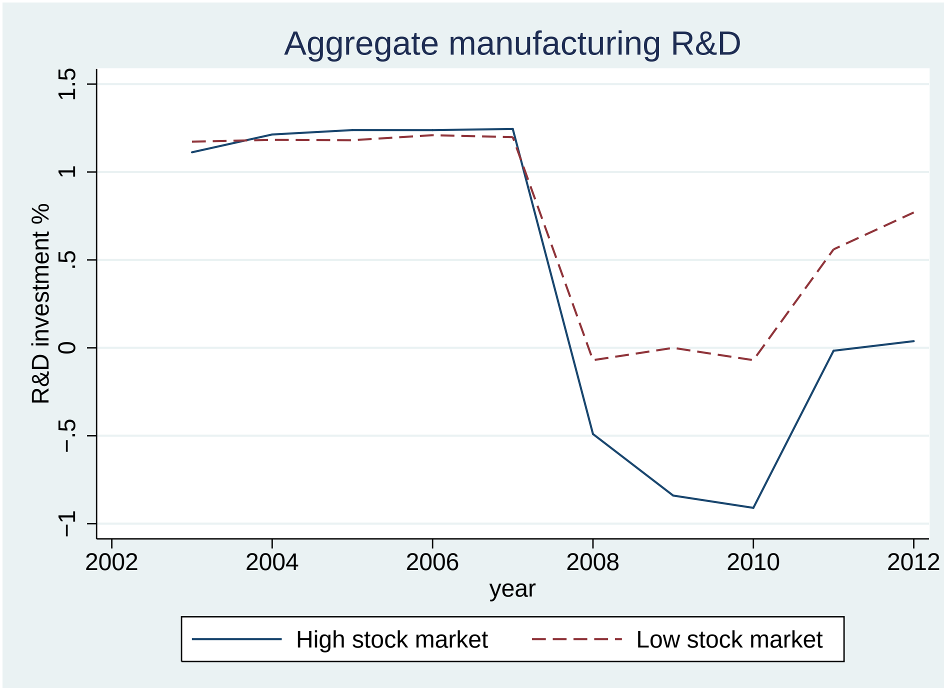

Figure 1.3: *Aggregate (manufacturing) R&D investment in countries with high versus low precrisis stock market influence (relative to the banking)*

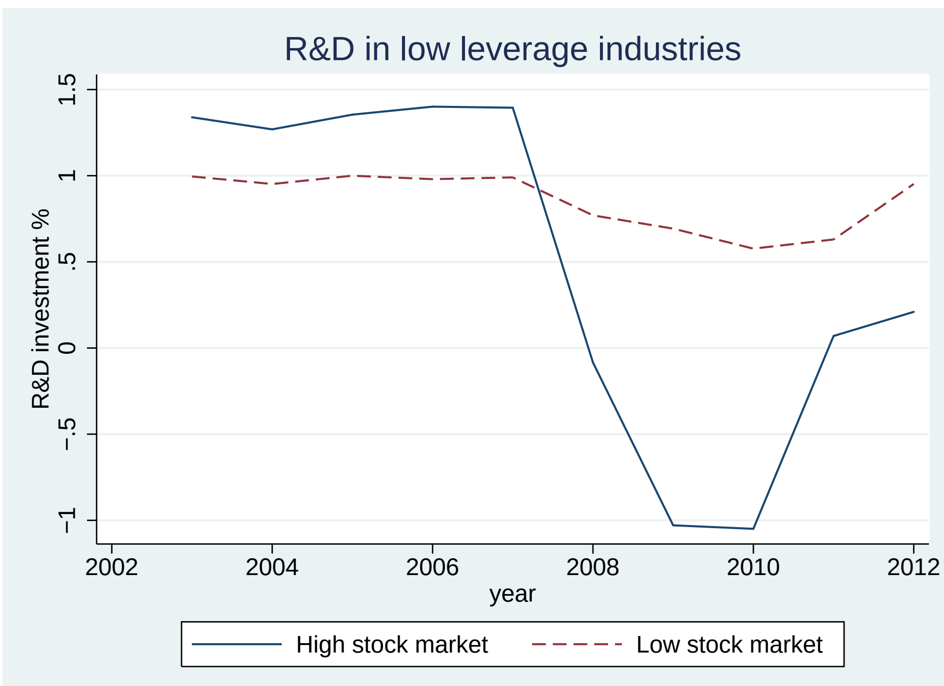

Figure 1.4: *R&D investment in industries with low precrisis leverage in countries with high versus low precrisis stock market reliance (relative to the banking)*

Dependent variable:	(1) Δ R&D investment	(2) Δ TFP
$Precrisis\ Low\ Leverage_{j,c} \times Post_t$	0.092	0.023
	(0.362)	(0.076)
$Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$	-0.330***	-0.196**
	(0.112)	(0.099)
Industry-Country F.E.	Yes	Yes
Industry-Year F.E.	Yes	Yes
Country-Year F.E.	Yes	Yes
Industry controls	Yes	Yes
No of observations	1,861	1,854
R square	0.657	0.489

Table 1.1: *Baseline results*

Dependent variable:	(1) Δ Non-R&D investment
$Precrisis\ Low\ Leverage_{j,c} \times Post_t$	0.112
	(0.162)
$Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$	-0.411*
	(0.210)
Industry-Country F.E.	Yes
Industry-Year F.E.	Yes
Country-Year F.E.	Yes
Industry controls	Yes
No of observations	1,861
R square	0.437

Table 1.2: *Baseline results: Non-R&D investment*

Dependent variable:	(1) Δ R&D investment	(2) Δ TFP
$Precrisis\ Low\ Leverage_{j,c} \times Post_t$	0.014	0.011
	(0.362)	(0.076)
$Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$	-0.101**	-0.025
	(0.047)	(0.15)
Industry-Country F.E.	Yes	Yes
Industry-Year F.E.	Yes	Yes
Country-Year F.E.	Yes	Yes
Industry controls	Yes	Yes
No of observations	4,862	4,799
R square	0.253	0.261

Table 1.3: *Baseline results: All sectors*

Dependent variable:	(1) Δ R&D investment	(2) Δ TFP
$Precrisis\ Stock\ Dependence_j \times Post_t \times Precrisis\ Stock\ Market_c$	-0.390**	-0.213*
	(0.191)	(0.110)
Industry-Country F.E.	Yes	Yes
Industry-Year F.E.	Yes	Yes
Country-Year F.E.	Yes	Yes
Industry controls	Yes	Yes
No of observations	1,863	1,862
R square	0.538	0.629

Table 1.4: *Results from the alternative specification*

Dependent variable:	(1) Δ R&D investment	(2) Δ TFP
$Precrisis\ High\ Tech_j \times Post_t \times Precrisis\ Stock\ Market_c$	-0.359**	-0.201**
	(0.178)	(0.091)
Industry-Country F.E.	Yes	Yes
Industry-Year F.E.	Yes	Yes
Country-Year F.E.	Yes	Yes
Industry controls	Yes	Yes
No of observations	1,863	1,862
R square	0.544	0.612

Table 1.5: *Results from the alternative specification: High-technology industries*

PANEL A	Placebo test: 2001	Period 2005-2010	Median leverage	2007 leverage	Stock market dummy
$Precrisis\ Low\ Leverage_{j,c} \times Post_t$	-0.031	0.053	0.091	0.092	0.084
	(0.112)	(0.317)	(0.299)	(0.338)	(0.367)
$Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$	-0.222	-0.451***	-0.335***	-0.347***	-0.385***
	(0.184)	(0.116)	(0.111)	(0.109)	(0.104)
Industry-Country F.E.	Yes	Yes	Yes	Yes	Yes
Industry-Year F.E.	Yes	Yes	Yes	Yes	Yes
Country-Year F.E.	Yes	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes	Yes	Yes
No of observations	1,623	1,861	1,861	1,861	1,861
R square	0.345	0.683	0.653	0.655	0.656
PANEL B	Value of stocks traded	Financial development	Trade opennes		
$Precrisis\ Low\ Leverage_{j,c} \times Post_t$	0.090	0.021	0.078		
	(0.351)	(0.119)	(0.299)		
$Precrisis\ Low\ Leverage_{j,c} \times Post_t \times Precrisis\ Stock\ Market_c$	-0.332***	-0.351***	-0.340**		
	(0.110)	(0.123)	(0.171)		
Industry-Country F.E.	Yes	Yes	Yes		
Industry-Year F.E.	Yes	Yes	Yes		
Country-Year F.E.	Yes	Yes	Yes		
Industry controls	Yes	Yes	Yes		
No of observations	1,861	1,861	1,861		
R square	0.656	0.667	0.659		

Table 1.6: *Robustness tests*

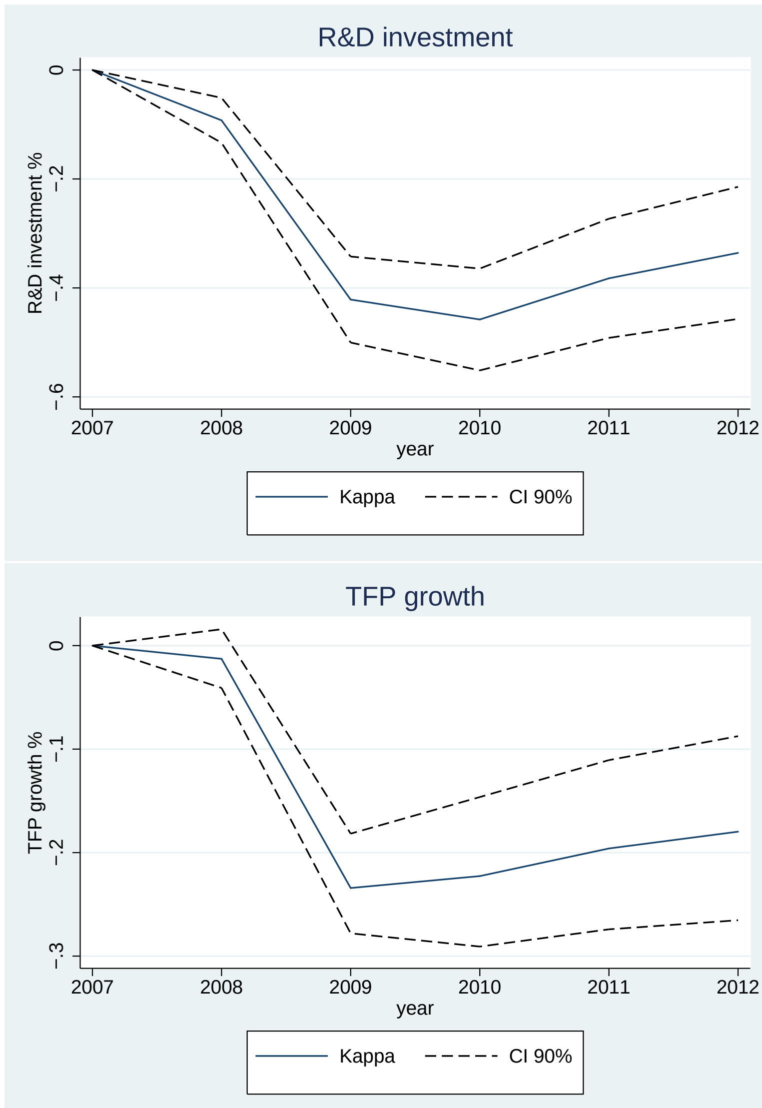

Figure 1.5: *Dynamic effects on the R&D investment and TFP growth in the postcrisis years*

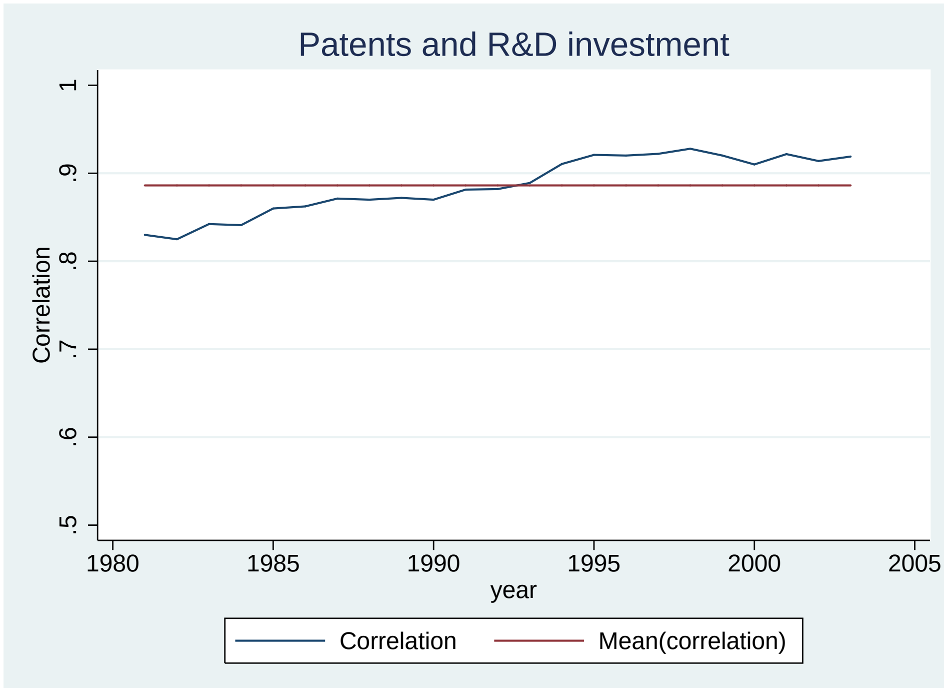

Figure 1.6: *Correlation between R&D investment and number of patents.*

Industry	NACE Code
Food products, beverages and tobacco	10-12
Textiles, wearing apparel, leather and related prodcuts	13-15
Wood and paper products; printing and reproduction of recorded media	16-18
Coke and refined petroleum products	19
Chemicals and chemical products	20-21
Rubber and plastics products, and other non-metallic mineral products	22-23
Basic metals and fabricated metal products, except machinery and equipment	24-25
Electrical and optical equipment	26-27
Machinery and equipment n.e.c.	28
Transport equipment	29-30
Other manufacturing; repair and installation of machinery and equipment	31-33

Table 1.7: *Industry classification in KLEMS*

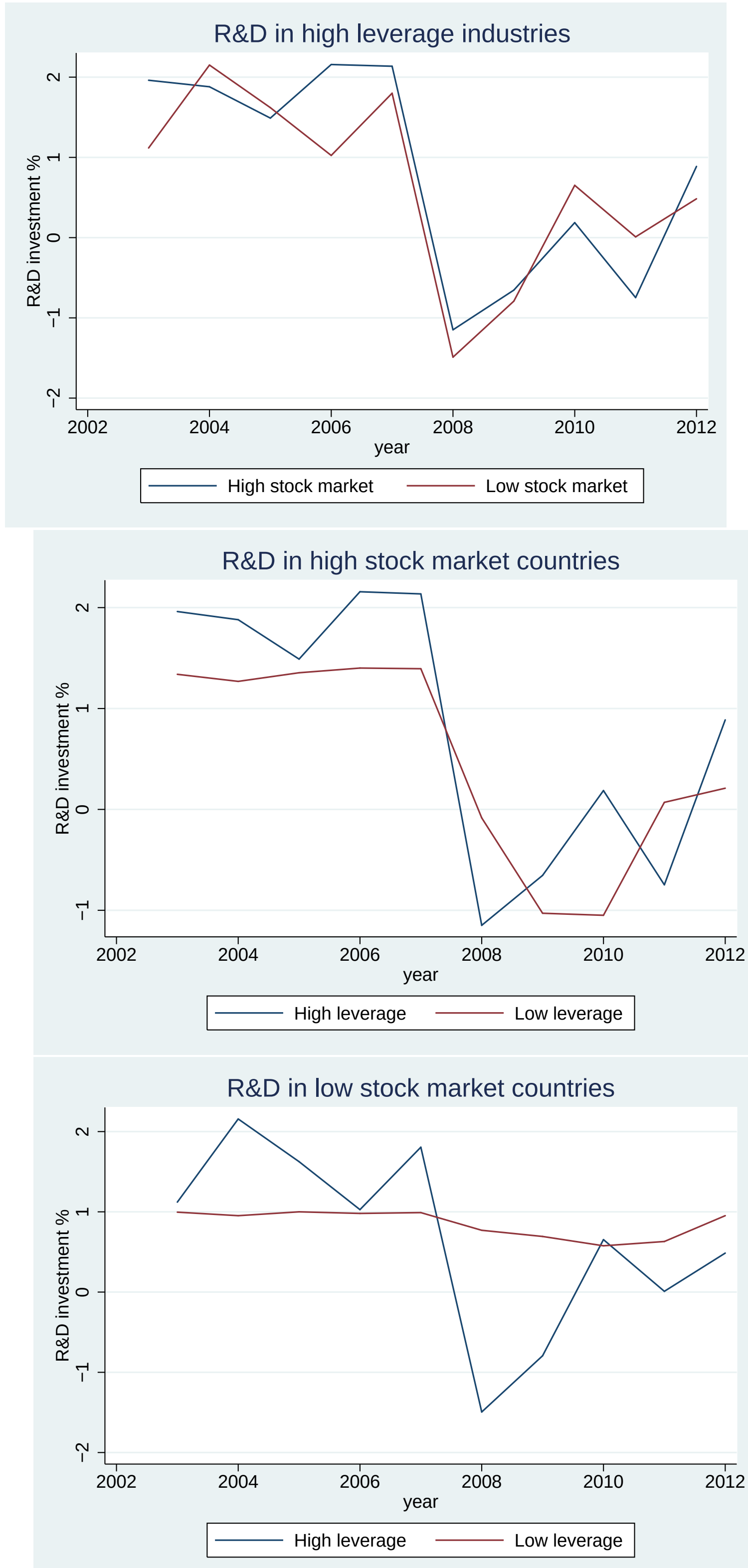

Figure 1.7: *R&D investment in industries with different precrisis leverage in countries with high versus low precrisis stock market reliance (relative to the banking*

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Chapter 2: Macroeconomic Policy, Product Market Competition, and Growth: The Intangible Investment Channel

2.1 Introduction

There is growing evidence that recessions accompanied by financial crises are associated with large permanent output losses, although the magnitude of these is still being debated (Cerra and Saxena, 2008; Jorda, Schularick and Taylor, 2013; Reinhart and Rogoff, 2009; Romer and Romer, 2017). Even more puzzling, some have argued that even plain vanilla recessions are followed by permanently lower output (Blanchard, Cerutti and Summers, 2015). The causes of such large and persistent output losses remain to be determined, but the potential implications for economic theory and policy are dauntingin particular, this gives rise to the possibility that counter-cyclical macroeconomic policy persistently or even permanently affects growth. This paper focuses on the role of intangible investment as a transmission channel. Using cross-country firm-level data and focusing on the 2008-2009 global financial crisis, we show that counter-cyclical macroeconomic policy alleviates intangible investment cuts by credit-constrained firms when financial conditions tighten. We also find that product market competition has the opposite effect, pointing to a complementarity between market deregulation and counter-cyclical macroeconomic policy for growth.

Intangible asset investment is an increasingly important driver of economic growth in advanced economies (Corrado et al., 2005; Corrado et al., 2009).[1] Even focusing only on those intangible assets currently captured in national accounts, and leaving aside other possible sources of under-measurementsuch as inaccurate deflatorssimple growth accounting suggests that intangible capital accumulation contributed about a third to overall labor productivity growth in the European Union and the United States over the 2000-2013 period (Corrado et al., 2016).[2]

However, intangible investment is also a potentially vulnerable growth driver. Becauseunlike tangible investmentit cannot generally be pledged against collateral or liquidated quickly, it is likely to be particularly vulnerable to continued availability of external or internal sources of finance. Moreover, the inherent uncertainty regarding the outcome of intangible investment magnifies asymmetric information and moral hazard problems would prevail (Hall and Lerner, 2010). For example, building on the work of Holmstrom and Tirole (1997), Aghion et al. (2010) show theoretically that credit constraints can lead firms to cut R&D spendingand long-

[1]At the firm level, structural estimation of various dynamic models of R&D also point to a significant role of R&D in determining the evolution of productivity over time (e.g., Aw et al., 2011; Doraszelski and Jaumandreu, 2013).

[2]Only a few intangible assets are currently capitalized in national accounts (SNA 2008), namely R&D, mineral exploration, computer software and databases, as well as entertainment, literary and artistic originals. Expenditures for design, branding, new financial products, organizational capital and firm-provided training are instead currently treated as intermediate costs.

term illiquid investments more broadlyduring recessions. In turn, more volatile R&D spending can undermine long-term growth if research projects need continuity to bear fruit.

Macroeconomic policy and product market competition and monetary policy should have a bearing on the availability and/or cost of internal and external finance, and thereby on the resilience of intangible investment to sudden shifts in credit conditions. Monetary and fiscal policies have an indirect impact on firms credit constraints through their effect on output, while monetary policy also influences the cost and availability of bank and non-bank credit (Aghion et al., 2010; Aghion, Hemous and Kharroubi, 2014; Correa-Caro et al., 2018). Likewise, product market competition drives down product market rents and, thereby, the amount of internal funds available for investment projects. For these reasons, there should also be some complementarity between product market reforms and active counter-cyclical monetary policy. The argument runs as follows. Product market deregulation can boost growth,[3] and as such features high on the policy agenda in many advanced economies,[4] but it also reduces product market rents. As a result, monetary policyand, more broadly, counter-cyclical macroeconomic policycan be more powerful in

[3]The existence of gains from easing barriers to entry in product markets has gradually become consensual since at least Blanchard and Giavazzi (2003) (e.g. Ebell and Haefke, 2009; Fang and Rogerson, 2011; Felbermayr and Prat; 2011). A strand of studies using country-time or country-time-industry panel data documents a significant positive effect of product market reform on productivity, investment, employment and/or output (e.g. Aghion et al., 2009a; Alesina et al., 2005; Bassanini and Duval, 2009; Bourles et al., 2013; Bouis, Duval and Eugster, 2016; Conway et al., 2006; Fiori et al., 2012; Inklaar et al., 2008; Nicoletti and Scarpetta, 2003). A related firm-level literature provides evidence on the impact of competitive pressures on innovation, technology adoption and productivity (e.g. Aghion et al., 2004, 2005; 2009b; Arnold et al., 2016; Gal and Hijzen, 2016).

[4]See, for example, Draghi (2015), IMF (2015, 2016), or OECD (2016).

stabilizing intangible asset investment and fostering longer-term growth in a more deregulated economy. Aghion, Farhi and Kharroubi (2018) build up a model that delivers these predictions, and provide supportive evidence using industry- and firm-level data. In particular, using data for over 2000 listed firms in selected European economies, they find that the European Central Banks Outright Monetary Transactions Program announced in 2012 had a larger positive impact on firms sales and employment growth in industries where market concentration measures (Herfindahl indices) were low than in more concentrated industries.

In this paper, we use a large cross-country firm-level dataset of several millions firm-year observations (ORBIS) to test directly for the impact of the countercyclicality of monetary (and fiscal) policy on intangible asset investment, and investigate how this impact varies depending on direct measures of product market competition.

Our empirical approach is a differences-in-differences strategy that exploits the sharp and unforeseen tightening of credit conditions that took place in the immediate aftermath of the collapse of Lehman Brothers on September 15th 2008. Using an extensive cross-country firm-level dataset put together by merging different waves of ORBIS, we start by showing, in line with Duval, Hong and Timmer (2017), that firms with greater pre-crisis balance sheet vulnerabilitieshigher leverage or, alternatively and as a robustness check, a higher interest expense burdenreduced their intangible investment rate more than their less vulnerable counterparts in the aftermath of the crisis. This holds within narrowly defined country-industry cellsthat is, controlling for any country-industry (supply or demand) shocks, and then comparing firms with strong vs. weak balance sheet vulnerabilities within each cell. This finding is not driven by more vulnerable firms having experienced slower intangible investment growth already before the crisismore and less vulnerable firms do not differ significantly along these or other relevant dimensions. Instead, the results are consistent with the view that when credit markets froze after September 15th 2008, more exposed firms were forced to reduce expenditure, particularly on items, such as intangible investment, that could not be pledged as collateral or translate quickly into sales. Indeed, we also find that the investment drop associated with balance sheet vulnerability was larger for intangible assets than for tangible ones.

Having established that financial frictions mattered for firm-level intangible investment after the crisis, we then explore the role of monetary (and fiscal) policy in mitigating their impact. Using various measures of the response of monetary (and fiscal) policy to the Lehman shock, we find a strong and statistically significant interaction with our measures of firm-level balance sheet vulnerabilities; monetary policy easing dampened the adverse impact of financial frictions on firms intangible asset investment.

Finally, using various measures of product market competition at the country- or country-industry-level, including Lerner indices and markups, we find that monetary policy was more powerful at stabilizing intangible investment after the collapse of Lehman Brothers where product market competition was stronger, that is, where product market rents were lower. This key finding highlights the complementarity between product market reforms and monetary policy. Product market deregulation should come hand in hand with aggressive counter-cyclical monetary policyand macroeconomic policy more broadlyto shelter intangible asset investment from macroeconomic shocks. Otherwise, there is a risk that the well-documented growth benefits from deregulation might be undermined by their side effect on intangible investment stability.

This paper relates to the existing studies on the permanent output costs of financial crises we mentioned above, but also to a related literature on macroeconomic volatility and long-term growth. Ramey and Ramey (1995) point to a negative cross-country correlation between volatility and growth. Aghion et al. (2010) focus on intangible investment as one channel through which such link may arise. They show theoretically that in the presence of credit constraints, adverse macroeconomic shocks will lead firms to cut spending on intangible and other forms of long-term, illiquid, but high-return forms of investment. Focusing on R&D spending, Aghion et al. (2012) provide supportive empirical evidence on French firm-level data. Using cross-country-industry panel data, Aghion, Hemous and Kharroubi (2014) find that counter-cyclical fiscal policy mitigates the impact of credit constraints on country-industry-level output growth. Aghion, Farhi and Kharroubi (2018) focus instead on monetary policy, introduce the interaction between monetary policy and product market competition, and use both industry- and (listed) firm-level data. Both papers focus on output growth without investigating the possible channel(s) at play. Also, competition is measured indirectly through broad indices of market concentration among a small set of listed firms, with well-known practical and conceptual limitations; in particular, competing non-listed domestic firms andeven more importantly in the case of highly open European economiesforeign firms are ignored in the calculations, while market contestability cannot be accounted for (Baumol, 1982). In this paper, we address both issues. We explore how intangible investment at the firm level is affected by monetary (and fiscal) policy and its interplay with direct measures of product market competition at the 4-digit industry level, including (firm-level based) Lerner indices and markups a la De Loecker and Warzynski (2012).

Also related to this paper is the recent literature on how the 2008-2009 global financial crisis (GFC) affected firms. Using firm-level data for the U.S., several papers find that financial frictions amplified the adverse impact of the GFC on employment; those firms with weaker corporate balance sheets (Giroud and Mueller, 2017; Dinlersoz et al., 2018), that had a relationship with weak banks (Chodorow-Reich, 2014), faced greater refinancing risk (Benmelech, Bergman and Seru, 2011) or were smaller and younger (Siemer, 2016) experienced greater job losses, all else equal. Other papers focus on the productivity losses from such financial frictions, such as De Ridder (2016) for U.S. firms, Huber (2017) for German firms and counties, or Duval, Hong and Timmer (2017) for a cross-country panel of firms. The latter paper also explores the effect of financial frictions on the response of firm-level intangible investment to the GFC. We extend their analysis to the role of counter-cyclical monetary (and fiscal) policy and its interplay with product market competition.

The remainder of this paper is structured as follows. Section II outlines our empirical strategy and the dataset employed in this study. Section III presents our econometric results. Section IV concludes.

2.2 Empirical Strategy and Data

2.2.1 Empirical Strategy

The baseline empirical strategy is set on a differences-in-differences framework, thereby comparing the difference in investment in intangible assets between firms with different levels of financial vulnerabilities, before and after the drastic unforeseen credit tightening that followed the collapse of Lehman Brothers.

Our methodology bears similarities with Giroud and Mueller (2017), who investigate the impact of this credit supply shock on firm-level employment in the U.S. by regressing the change in firm-level employment around the global financial crisis on the pre-crisis leverage ratio which is the measure of firm-level credit constraint. A similar approach is employed in Kalemli-zcan et al. (2018) to study the effect of financial factors on the slowdown in tangible investment in European countries. Duval et al. (2017) apply this methodology to investigate the role of firm-level financial constraints in the productivity slowdown in advanced countries following the GFC. In a first stage, in line with them, we begin by estimating:

$$\Delta \; Intangible \; Investment_{i,s,c} = \beta_1 Financial \; Vulnerability_{i,s,c} + \delta_{s,c} + \gamma \mathbf{X}_{i,s,c} + \epsilon_{i,s,c} \quad (2.1)$$

where $\Delta \; Intangible \; Investment_{i,s,c}$ is the difference in the average investment in intangible assets (scaled by total assets) of firm i, in industry s and country c between the pre-crisis (2002-2007) and post-crisis (2008-2013) periods. $Financial \; Vulnerability_{i,s,c}$ is a measure of pre-crisis balance sheet vulnerability, details of which are discussed below. $\delta_{s,c}$ denotes country-sector fixed effects, absorbing all the country-sector level characteristics that might commonly affect firm-level changes in intangible investment between the two periods in a given country-sector where sectors are highly disaggregated at 4-digit NACE level.[5] In effect, this implies that we will be comparing the impact of the Lehman shock on intangible investment between strong- and weak-balance-sheet firms firms within a given country-sector. Finally, $\mathbf{X}_{i,s,c}$ is a set of firm-level controls including age, total assets and cash flows (ratio of cash flows to assets) in the pre-crisis period. Our rich set of country-sector fixed effects and firm-level controls addresses key sources of omitted variable bias, while reverse causality is not a concern in our set-up since firm-level development within each 4-digit country-sector are highly unlikely to influence monetary policy.

[5] For instance, intangible investment in some sectors relying more heavily on external finance than others may have been on average more affected by the GFC. Similarly, export-intensive industries in a more export-oriented country may have been affected differently following the great trade collapse. All such potential channels that are specific at the country-industry level but common across firms in that specific country-industry will be controlled by country-sector fixed effects.

In a second stage, once β_1 is tested to be negative, implying that firm-level financial vulnerabilities had an adverse effect on intangible investment, we turn to the counteracting effect of counter-cyclical macroeconomic policy. To do so, we exploit the cross-country heterogeneity in the response of monetary conditions to the GFC and estimate:

$$\Delta\ Intangible\ Investment_{i,s,c} = \beta_1 Financial\ Vulnerability_{i,s,c}$$
$$+\beta_2 Financial\ Vulnerability_{i,s,c} \times Expansionary\ Conditions_c$$
$$+\delta_{s,c} + \gamma \mathbf{X}_{i,s,c} + \epsilon_{i,s,c} \tag{2.2}$$

where $Expansionary\ Conditions_c$ is a measure, discussed in detail further below, of the extent to which monetary conditions eased after the GFC owing to counter-cyclical macroeconomic policies. In this specification, together with $\beta_1 < 0$, $\beta_1 < 0$ would imply that expansionary monetary conditions dampen anddepending on its magnitude and the estimated values of β_1 and $\beta_2$even possibly offset the negative impact of financial vulnerabilities on the response of intangible investment to the credit supply shock.

In a third and final stage, we explore the complementarities between counter-cyclical macroeconomic policies and product market deregulation. The theoretical underpinnings are laid out in Aghion, Farhi and Kharroubi (2018). They develop a model in which firms decide on the amount of investment in a growth-enhancing form of capital in the presence of profitability and liquidity shocks. In their set-up, strong product market competition reduces profits, the ability of firms to weather liquidity shocks and, thereby, investment. They also show that by mitigating the impact of liquidity shocks, counter-cyclical monetary policy incentivizes firms to invest more, particularly so where strong product market competition depresses profits.

In our empirical set-up, these considerations yield two testable implications that can be checked by estimating the following specification:

$$\begin{aligned}
\Delta\ Intangible\ Investment_{i,s,c} &= \beta_1 Financial\ Vulnerability_{i,s,c} \\
&+\beta_2 Financial\ Vulnerability_{i,s,c}\ Conditions_c \\
&+\beta_3 Financial\ Vulnerability_{i,s,c} \times Weak\ Competition_{s,c} \\
&+\beta_4 Financial\ Vuln_{i,s,c} \times Expansionary\ Condit_c \times Weak\ Competition_{s,c} \\
&+\delta_{s,c} + \gamma \mathbf{X}_{i,s,c} + \epsilon_{i,s,c}
\end{aligned} \tag{2.3}$$

where $Weak\ Competition_{s,c}$ is a proxy measure for the degree of product market competition, which will be discussed in detail below. First, the adverse effect of corporate balance sheet weakness on intangible investment in the aftermath of the Lehman collapse should be greater for firms facing higher competition; this implies $\beta_3 > 0$. Second, the beneficial impact of expansionary monetary conditions should be greater for firms facing higher competition, that is, β_4 should be negative. Standard errors will be clustered at the country-sector level.

2.2.2 Data

Firm-level variables

Our firm-level variables are constructed using ORBIS, a cross-country longitudinal dataset of both listed and unlisted firms provided by Bureau van Dijk. The dataset features rich information on firms activities and financial variables based on balance sheets and income statements. We refer the reader to Diez et al. (forthcoming) for a more detailed description of the dataset and the approach taken to clean the data, which essentially follows similar steps as in Kalemli-zcan et al. (2015) and Gopinath et al. (2017).[6]

We focus on 17 OECD countries for which we have data on both firm-level and country-level macroeconomic variables over this period, namely Austria, Belgium, Czech Republic, Germany, Finland, France, Greece, Hungary, Ireland, Italy, Korea, Norway, Poland, Portugal, Slovakia, Spain, UK. We study firms in the non-farm, non-financial business sector, which corresponds to the two-digit industry codes 5-82 in NACE Revision 2., covering both manufacturing and a number of service sectors (e.g. real estate and profession/scientific/technical activities). Basic firm-level summary statistics are provided in Table 2.1.

[6] To ensure consistency and comparability of monetary variables across countries and over time, time-industry varying value-added or gross output deflators are applied to convert nominal monetary variables to real variables in 2010 constant USD for non-capital variables, while the country-level investment deflators from the World Development Indicators database are applied for capital variables. Importantly, any heterogenous changes in country-industry-level capital price deflators will be absorbed by the country-sector fixed effects included in specifications (2.1)- (2.3). In addition, observations with likely reporting errors due to concerns related to the reliability of the data as well as the consistency of variables over time are excluded.

Our main dependent variable of interest is the change in intangible investment, defined as difference in average investment in intangibles as a share of total assets between pre- and post-crisis periods. We measure investment in intangibles on a net basisthat is, net of depreciation (or amortization), computing it as the change in real intangible assets. One potential concern regarding this measure stems from the highly complex nature of international standards for intangible assets accounting.[7] In practice, the intangible assets reported on firms balance sheets tend to be mostly acquired assetswith a clear transaction price, such as patents or softwareor internally-generated ones at the development phaseand thereby with estimable future economic benefits. This leaves out other types of internally-generated intangibles, most notably R&D projects at the research stage. Therefore, intangible assets are likely to be both imperfectly reported and under-reported. As a result, our econometric analysis is likely to be subject to classical measurement error in the dependent variable, leading to attenuation bias and overly conservative resultsagainst finding any statistically significant relationship. We will also check the robustness of our results to alternative measures of the dependent variable.

To explore the role of firm-level financial vulnerabilities for intangible investment and their interplay with policies, we consider two variables that capture po-

[7] In principle, intangible assets include, but are not limited to, scientific or technical knowledge, design and implementation of new processes or systems, licenses, intellectual property, market knowledge and trademarks such as brand names and publishing titles. According to International Accounting Standard (IAS) 38, however, only those that meet three criteriaidentifiability, controllability, and estimabilityshould be recorded on the balance sheet.

tential financial constraints faced by firms. The baseline measure is the pre-crisis average of leverage ratio to capture the degree of debt overhang risk. Giroud and Mueller (2017) discuss that U.S firms with a higher pre-crisis leverage ratio faced more acute financial constraints when credit conditions tightened afterwards. This is calculated as the ratio of the sum of current liabilities and long-term debt to total assets for corresponding periods. As a robustness check, we also consider the interest coverage ratio prior to the crisis, defined as total interest paid by the firm over its earnings before taxes, depreciation and amortization of capital (EBITDA). This is supposed to capture the degree of drags on financing that stem from debt payments (Kalemli-zcan et al., 2018). Since the Lehman shock to credit conditions was unforeseen, firms debt structure prior to this event is unlikely to be correlated with other unobserved firm-level characteristics that may be correlated with the change in intangible investment after the crisis.

Macroeconomic policy conditions

Post-crisis monetary conditions in a given country are measured in four alternative ways. The baseline measure is the average forecast error of long-term (10 year) government bond yields in the post-crisis period, relative to OECD forecasts for the year considered, as published in the Fall issue of the *OECD Economic Outlook* in the previous year. This is intended to capture the surprise component of monetary conditions, that is, the extent to which they were more expansionary than expected post-crisis. One advantage of this measure, beyond its simplicity, is to capture relevant monetary conditions for firms better than short-term policy rates do, and to encompass the impact of both conventional and unconventional monetary policy measures that were implemented by major central banks after the crisis.

Alternatively, we consider more direct measures of monetary policy shocks. One is the deviation of the policy rate from its simple Taylor-rule-implied value in the post-crisis period, using standard Taylor rule parameters and following extensive previous literature (e.g. Bordo and Landon-Lane, 2013; Bruno and Shin, 2015; Coibion et al., 2017; DellAriccia, Laeven, and Suare, 2017). Another monetary policy shock measure is the forecast error of the short-term policy rate that is orthogonal to unexpected changes in output growth and inflation.[8] This is computed in two steps. In a first step, the difference between the actual and forecast short-term rate is calculated, along with similar differences for inflation and GDP growth, where the forecasts of short-term policy rates, inflation, and output growth are taken from *Consensus Economics* in October of the same year. In a second step, forecast errors for the short-term rate are regressed on forecast errors for inflation and GDP growth; residuals from this panel regression are then taken as the exogenous monetary policy shock in a given country and year.

Finally, since fiscal policy can ease firms credit constraints by raising aggre-

[8] See for example Duval and Furceri (2018).

gate demand and output (Aghion et al., 2012), we also consider a fiscal policy shock measure in an extension of our analysis. We use the forecast error of the ratio of government consumption to GDP, following Auerbach and Gorodnichenko (2012). The forecasts are taken from the Fall issue of the *OECD Economic Outlook* in the same year.

Product market competition measures

The degree of competition faced by firms is measured in three ways, two of which are derived from firm-level market power measures. The baseline measure is the (median value of the) Lerner index for each country-sector in the pre-crisis period. It is calculated as *(EBITDA-Depreciation and Amortization)/(Operating Revenue)* and represents an inverse measure of country-sector-level competition. Alternatively, we use firm-level markups. These are computed following the approach proposed by De Loecker and Warzynski (2012) and applied by De Loecker and Eeckhout (2017) or Diez et al. (forthcoming) to document rising corporate market power in advanced economies. We take the median of firm markups in each country-sector as a measure of (weak) competition.[9]

While firm-level-based measures are our preferred indicators because they aim to measure directly the strength of market competition and can be computed for

[9]We are grateful to Federico Diez, Jiayue Fan and Carolina Villegas-Sanchez for sharing the estimated markup data they calculated one the dataset used in the present paper.

each country-industry, we also confirm the robustness of our results to using instead the economy-wide product market regulation (PMR) indicators published by the OECD. These are based on responses by national governments to extensive questionnaires covering a wide range of anti-competitive product market regulations (for details, see Koske et al., 2015). In our analysis, we consider the overall PMR indicator but also, given our focus on the role of incumbent firms product market rents, two specific sub-indicators on barriers to entry and regulatory protection of incumbents.

2.2.3 Stylized Facts

For our differences-in-differences strategy to be valid, two conditions should be met. First, the 2008 GFC shock should be exogenous, and second, firms with different levels of financial vulnerabilities should have had a parallel trend in intangible investment growth prior to the crisis, with any divergence materializing only after the crisis. Regarding the first condition, there is broad consensus that the GFC was unforeseen by individual firms; for example, Cheng et al. (2014) show that even managers in the securitized finance industry failed to identify the housing bubble. The second condition requires a careful look at the data to ensure that our estimates will not be driven by more vulnerable firms having experienced slower intangible investment growth already before the crisis.

To this end, we run a regression of firm-level intangible investment growth on year dummies and four-digit country-sector fixed effects separately for high-leverage and low-leverage firms, where the leverage threshold used to split firms in those two groups is, in each country-sector separately, the median across firms of the average leverage ratio over the pre-crisis period. Panel A in Figure 2.1 reports the evolution of the year dummy variable derived from these regressionswhich basically captures average annual growth in intangible investment, expressed as a deviation from its country-sector average over the sample periodacross high-leverage (solid blue line) and low-leverage (solid red line) firms, respectively. The figure confirms that the second condition is satisfied: intangible investment by both sets of firms grew at a similar pace until the GFC, after which high-leverage firms started experiencing a greater decline in intangible investment than their low-leverage counterparts. Moreover, a corresponding chart for tangible investment in Panel B indicates that the post-crisis divergence between high- and low-leverage firms was less pronounced for tangible investment, supporting our underlying premise that intangible investment is likely to be more dependent on continuous availability of external or internal sources of finance due, in particular, to its inherently limited pledgeability.

Figure 2.2 illustrates the relevance of these changes in intangible investment for changes in total factor productivity (TFP) between the pre-crisis and post-crisis periods. The TFP series for each firm is derived here from the estimation of a production function with labor and tangible capital, using the GMM procedure proposed by Wooldridge (2009) to address the simultaneity problem stemming from the input choices and the firms productivity, and also the critique of Ackerberg, Caves and Frazer (2015). For each firm in the sample, the change in the intangible-to-total-assets ratio (in percent) between the pre- and post-crisis periods is calculated, and then ranked. The resulting data are then broken into 100 quantiles, for each of which the median value of the change in the intangible-to-total-assets ratio is calculated. Each dot in the figure represents this quantile-median, as a deviation from a country-sector fixed effect (x-axis). It is plotted against the quantile-median of the deviation of the change in average TFP growth from a country-sector fixed effect (y-axis). The post- and pre-crisis periods includes five years after and before the 2008 crisis, respectively. Overall, the figure shows a strong positive correlation between changes in intangible investment and TFP growth between the pre- and post-crisis periods, consistent with recent literature pointing to a sizeable impact of intangible capital on productivity (e.g., Aw et al., 2011; Doraszelski and Jaumandreu, 2013). Incidentally, Figure 2.2 also confirms that, although far from fully comprehensive, the intangible assets included in firm balance sheets do contain relevant information for productivity growth, and are therefore worth studying.

Now, we turn to investigating the role of financial frictions for intangible investment and their interplay with policies.

2.3 Empirical Results

2.3.1 Baseline estimates

Our starting point, as specified in (2.1), is to show, as in Duval et al. (2017), that firms with pre-existing balance sheet vulnerabilities tended to reduce intangible investment in the post-crisis period more than their less vulnerable peers within a given country-industry. The results are presented in Table 2.2. The estimated coefficient implies that firms with a 10 percentage point higher leverage ratio reduced their intangible investment rate more by around 0.05 percentage point (column 1). To get a better sense of the estimated effect, Figure 2.3 illustrates the difference in the estimated decline in intangible investment rate (relative to country-sector averages) between the 75th percentile (blue bar) and 25th percentile firms (shaded bar) in terms of the leverage ratio, which amounts to 0.15 percentage point (red bar).

Insofar as firms could still bring their physical assets as collateral or liquidate them to avoid cutting intangible investment expenditurewhich cannot be collateralized or liquidated easilythe extent to which firms cut intangible investment might be expected to be greater for firms that have few or no physical assets. To test for this, we further differentiate among firms depending on their asset pledgeability, measured as the share of tangible assets in total assets in the pre-crisis period, by interacting this measure with leverage. The results, which are reported in column (2) of Table 2.2, lend further support to the hypothesis that financial frictions affected intangible investment after the crisis: as shown by the statistical significance (at the 10% confidence level) of the interaction term, firms with a larger (smaller) share of physical assets turn out to have been less (more) affected by the tightening of credit conditions in 2008.

Turning to the role of expansionary monetary conditions in mitigating the adverse impact of financial constraints on intangible investment, Table 2.3 reports regression results from the specification (2.2) in column 1. The positive and statistically significant coefficient estimate on the interaction term implies that more expansionary monetary conditions could dampen, and indeed prevent, a cut in intangible investment by financially-constrained firms. The size of the coefficient estimates is such that a more-than-expected reduction in the long-term external financing cost of some 100 basis points fully negates the adverse impact on intangible investment stemming from debt overhang risk. Figure 2.4 contrasts the estimated effects for firms with high and low leverage under two different scenariosmore-than-expected expansionary (right bars) and contractionary monetary conditions (left bars) by 50bpssuggesting that adverse effects of financial frictions on intangible investment can be reduced by one-third under the cases considered (red bars in the middle).

These estimates have sizeable implications for output. A back-of-the-envelope calculation of the output effects of weaker post-crisis intangible investment in more leveraged firms requires using an elasticity of output with respect to intangible capital, for which available estimates tend to vary substantially across data samples and methodologies, ranging roughly from 20 to 40 percent (Doraszelski and Jaumandreu 2013; Hall et al., 2010). Based on this range, our estimation results would imply that a 100 basis points negative surprise on monetary conditions could prevent a cumulative output loss of 1 to 2 percent for high-leverage firms (75th percentile of the leverage distribution) vis--vis their low-leverage counterparts over the five years after the crisis.[10]

As an intermediate step toward investigating potential complementarity between monetary and competition policies, we first check if competition had any impact on relationship between financial frictions and intangible investment. Our premise is that the adverse effects of financial frictions on intangible investment should have been greater for firms facing high competition because, unlike their low-competition counterparts, they could not use monopoly rents to keep on financing intangible investment after the crisis. Regression results in column 2 of Table 2.3 support this view: we find that financial constraints have a larger adverse effect on intangible investment when competition is stronger (i.e., when the country-sector median Lerner index is lower).

[10]The 0.15 percentage points difference in the decline in the intangible-investment-to-total-assets ratio in Figure 2.1 corresponds to about a 1 percentage point difference in the intangible-investment-to-intangible-assets ratio, or about a $1 \times 5 = 5$ percent cumulative loss in intangible capital. Applying a 20 to 40 percent return on this capital implies a 1 to 2 percent output loss in the high-leverage firm vis--vis its low-leverage counterpartwhich, per the estimates in Table 2.3, is therefore the output loss prevented by a 100 basis points negative surprise on monetary conditions. Note that this back-of-the envelope calculation is performed only within each country-sector. We conjecture that the aggregate effects of financial frictions on intangible investment, and thereby on output, are also likely to have played out across country-sectors, with the more leveraged among them being more affected. Any such effects are absorbed by our 4-digit country-sector fixed effects here.

We then examine potential complementarity between monetary and competition policies by running a regression of the specification (2.3). To the extent that expansionary monetary conditions could help alleviate the adverse impact of financial constraints on intangible investment (column 1) and that such adverse effects are particularly strong in a more competitive environment (column 2), it should be the case that the role of counter-cyclical macroeconomic policy is more pronounced for firms facing high competition, suggesting potential complementaritycounter-cyclical policy that prevents a slowdown in intangible investment by constrained firms is more effective in a more competitive environment. This is precisely what column 3 in Table 2.3 reports as illustrated in Figure 2.4. Coefficient estimates on the triple interaction term is negative and statistically significant, reinforcing the alleviating role of expansionary conditions when firms face stronger competition. These results provide evidence of a complementarity between pro-competition product market reforms and counter-cyclical macroeconomic policy.

The estimated magnitude of this complementarity between pro-competition product market reforms and counter-cyclical macroeconomic policy is illustrated in Figure 2.4, which is an extension of Figure 2.3. Specifically, when product market competition is stronger (at the 25th percentile of the pre-crisis distribution of Lerner indices), the estimated cut in intangible investment by more-leveraged firms relative to their less-leveraged counterparts can be reduced from 0.25 to 0.08 percentage point when monetary conditions are more rather than less expansionary than expected (green shaded bars on the left). When competition is weaker (at the 75th percentile of the Lerner index distribution), the corresponding numbers are smaller at 0.16 and 0.05 (green shaded bars on the right), and so is the difference between them0.25-0.08=0.17 versus 0.16-0.05=0.11 (red solid and shaded bars in the middle), implying an overall 50% stronger effect of counter-cyclical macroeconomic policies in more competitive environments.

Table 2.4 checks whether our baseline results reflect the effects on intangible investment only or also capture those relative to tangible investment. We replace the dependent variable with the difference in the average ratio of intangible to tangible assets (column 1) or the difference in the average investment in tangible assets (scaled by total assets; column 2), both between the pre- and post-crisis periods. The estimation results confirm that the identified channelfinancial frictionsthrough which counter-cyclical macroeconomic policies and product market competition shape the response of investment to credit conditions is more pronounced for intangible assets than it is for tangible ones.

2.3.2 Extensions and Robustness Checks

We perform a wide range of sensitivity analyses on our results. In particular, we show that our findings are robust to alternative measures of expansionary macroeconomic policies, product market competition, and firm balance sheet vulnerability.

Table 2.5 confirms that the baseline results are robust to alternative measures of expansionary monetary conditions. Keeping the baseline competition measure, we alternate the policy shocks measures: the deviation of the actual policy rate from Taylor-rule implied rate (column 1); the forecast error of the actual short-term rate that is orthogonal to changes in inflation and output growth (column 2); the forecast error of the government consumption expenditure to GDP (column 3). All of them show qualitatively identical results to the baseline results reported in Table 2.3. In particular, all double and triple interactions terms featured in column (3) of Table 2.3 remain statistically significant, with the partial exception of the triple interaction term testing for the complementarity between competition and counter-cyclical monetary policy, which is only borderline significant (at the 10% level) when the forecast error of the short-term rate is used.

Likewise, Table 2.6 confirms that the baseline results are robust to alternative measures of product market competition. This time, we keep the baseline monetary condition measure, and alternate the competition measures: the country-sector median of estimated markups (column 1); OECDs overall product market regulation (PMR) indicator (column 2); OECDs sub-indicator on regulatory protection of incumbents (column 3); OECDs sub-indicator on administrative burdens on start-ups. All columns indicate qualitatively identical results to the baseline results, with all relevant effects showing statistical significance at the 1% confidence level.

We conduct three additional sets of robustness checks on the sample, baseline specification and firm-level balance sheet vulnerability variable, whose results are summarized in Table 2.7. First, we shorten the time window to 2005-2010 (two years before versus two years after the GFC), which also has the advantage of fully removing the 2010-2012 euro area crisis period. Since the adverse effects of financial frictions are likely to have been more acute right after the crisis, we expect the estimated effects to be at least as big as the baseline results. This is confirmed by slightly larger point estimates in absolute terms compared to those from the baseline estimation (column 1).

Second, we check the robustness of our results to an alternative measure of firm-level financial vulnerability, namely the interest coverage ratio. The higher the ratio is, the greater the debt burden is, and the more vulnerable the firm should be to a tightening of credit conditions. Again, this yields qualitatively identical results to the baseline regression (column 2).

Lastly, given that intangible investment data are potentially noisy, as discussed earlier, we replace the dependent variable with a dummy variable that takes value 1 for non-negative changes in net intangible investment between the pre- and post-crisis periods, and 0 otherwise (negative change). This linear probability model has the advantage of being potentially less prone to measurement error in the dependent variable. Again, results are qualitatively identical to the baseline specification (column 3). In a similar vein, we exclude those firms that have never had any intangible assets throughout the sample periodabout 10 percent of the full sample. The estimation results are almost identical to the baseline results, with slightly bigger point estimates (column 4).

2.4 Conclusion

Investment in intangible assets is an increasingly important driver of economic growth but, being non-pledgeable as collateral and hard to liquidate quickly, it is also potentially vulnerable to financial frictions. This implies that counter-cyclical macroeconomic policy could strengthen longer-term growth by sheltering intangible investment from adverse shocks, particularly so where strong product market competition prevents firms from self-financing their investments through rents. Using a large cross-country firm-level dataset and focusing on the global financial crisis and its aftermath, this paper finds strong support for these theoretical predictions. Our results highlight a complementarity between pro-competition product market deregulation and counter-cyclical monetary (and fiscal) policy in fostering intangible investment and growth.

Our findings thus have strong implications for economic theory and policy that give rise to the possibility that counter-cyclical macroeconomic policy persistently or even permanently affects growth. Moreover, insofar as product market competition can backfire when credit constraints bite in downturns, our results call for strengthening countercyclical macro policies alongside any market deregulation to foster growth.

Table 2.1: *Summary Statistics*

Variable	Mean	Median	25th percentile	75th percentile	Standard deviation
Δ *Intangible Investment*	-0.0012	0	-0.0005	0.0023	0.0231
Δ *Tangible Investment*	-0.0140	0	-0.0315	0.0266	0.2080
Intangible / Total assets ratio	0.16	0.02	0	0.21	0.25
Leverage ratio	0.67	0.70	0.53	0.84	0.21

Note: Δ Intangible Investment is the difference in the average net investment in intangible assets (as a ratio of total assets) between post- and pre-crisis periods. Δ Tangible Investment is similarly defined. Intangible / Total assets ratio is the ratio of intangible assets to total (tangible+intangible) assets in the pre-crisis period. Leverage ratio is defined as the average debt-to-assets ratio in the pre-crisis period. Lerner index is computed as the average of (EBITDA-Depreciation and amortization)/Operating revenue in the pre-crisis period. This summary table is based on 664,086 observations of the baseline estimation sample.

Table 2.2: *Baseline Estimation Results: Intangible Investment and Leverage*

	(1)	(2)
$Vulnerability_{i,s,c}$	-0.005***	-0.014***
	(0.000)	(0.005)
$Vulnerability_{i,s,c} \times Pre-crisis\ physical\ assets\ ratio_{i,s,c}$		0.010*
		(0.006)
Observations	664,086	664,086
R-squared	0.061	0.065
Country-Sector FE	Yes	Yes

*Note: The dependent variable is the difference in the average net investment ratio in intangible assets (ratio of intangible to total assets) between post- and pre-crisis periods. Firm-level vulnerability is the average debt-to-assets ratio in the pre-crisis period. The post-crisis period starts in 2008. Firm-specific controls (included but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with the pre-crisis average ratio of physical assets in total assets. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level*

Table 2.3: *Baseline Estimation Results: Intangible Investment, Leverage and Macro Policies*

	(1)	(2)	(3)
$Vulnerability_{i,s,c}$	-0.005***	-0.007***	-0.009***
	(0.000)	(0.001)	(0.001)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c$	0.005***		0.009***
	(0.001)		(0.001)
$Vulnerability_{i,s,c} \times Weak\ competition_{s,c}$		0.047***	0.061***
		(0.011)	(0.013)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c \times Weak\ competition_{s,c}$			-0.074***
			(0.019)
Observations	664,086	664,086	664,086
R-squared	0.062	0.061	0.062
Country-Sector FE	Yes	Yes	Yes

*Note: The dependent variable is the difference in the average net investment in intangible assets (as a ratio of total assets) between post- and pre-crisis periods. Firm-level Vulnerability is measured as the average debt-to-assets ratio in the pre-crisis period. Expansionary monetary conditions is the average OECD forecast error for long term (10-year government bond) interest rate in the post-crisis period as a measure of more-than-expected policy loosening. Weak competition is measured as the median pre-crisis Lerner index value in each country-sector, reflecting the degree of profitablity. The post-crisis period starts in 2008. Firm-specific controls (included in regressions but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with Expansionary monetary conditions and/or Weak competition measures. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level.*

Table 2.4: *Baseline Estimation Results: Intangible Investment vs Tangible Investment*

	(1) Intangible to total assets ratio	(2) Investment in intangible assets
$Vulnerability_{i,s,c}$	-0.022***	-0.017***
	(0.004)	(0.003)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c$	0.027***	0.002
	(0.006)	(0.005)
$Vulnerability_{i,s,c} \times Weak\ competition_{s,c}$	-0.141***	-0.001
	(0.053)	(0.048)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c \times Weak\ competition_{s,c}$	-0.233***	0.007
	(0.079)	(0.075)
Observations	664,084	674,266
R-squared	0.012	0.033
Country-Sector FE	Yes	Yes

*Note: The dependent variable is the difference in the average ratio of intangible assets to total (tangible + intangible) assets between post- and pre-crisis periods in column (1); the difference in the average net investment in tangible assets (as a ratio of total assets) between post- and pre-crisis periods in column (2). Firm-level Vulnerability is measured as the average debt-to-assets ratio in the pre-crisis period. Expansionary monetary conditions is the average OECD forecast error for long term (10-year government bond) interest rate in the post-crisis period as a measure of more-than-expected policy loosening. Weak competition is measured as the median pre-crisis Lerner index value in each country-sector, reflecting the degree of profitablity. The post-crisis period starts in 2008. Firm-specific controls (included in regressions but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with Expansionary monetary conditions and/or Weak competition measures. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level.*

Table 2.5: *Alternative Measures of Macroeconomic Policy Shocks*

Expansionary policy is	(1) Deviation from Taylor rule	(2) Forecast errors in short term policy rate	(3) Forecast errors in gov't consumption
$Vulnerability_{i,s,c}$	-0.005***	-0.011***	-0.015***
	(0.001)	(0.001)	(0.001)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c$	0.004***	0.010***	0.014***
	(0.000)	(0.003)	(0.001)
$Vulnerability_{i,s,c} \times Weak\ competition_{s,c}$	0.019***	0.062***	0.099***
	(0.010)	(0.015)	(0.015)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c \times Weak\ competition_{s,c}$	-0.016**	-0.072*	-0.121***
	(0.006)	(0.038)	(0.017)
Observations	664,086	571,482	647,836
R-squared	0.063	0.062	0.063
Country-Sector FE	Yes	Yes	Yes

*Note: The dependent variable is the difference in the average net investment in intangible assets (as a ratio of total assets) between post- and pre-crisis periods. Firm-level Vulnerability is measured as the average debt-to-assets ratio in the pre-crisis period. Expansionary monetary conditionsas a measure of more-than-expected policy loosening is the average deviation of policy rates from the Taylor-rule implied one in the post-crisis period in column 1; the forecast error in monetary policy rates from Duval and Furceri (2018) in column 2; the forecast error of government consumption expenditure to GDP from Duval and Furceri (2018) in column 3. Weak competition is measured as the median pre-crisis Lerner index value in each country-sector, reflecting the degree of profitablity. Firm-specific controls (included in regressions but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with Expansionary monetary conditions and/or Weak competition measures. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level.*

Table 2.6: *Alternative Measures of Product Market Competition*

Competition measure is	(1) Median markup (country-sector)	(2) Product market regulation	(3) Regulatory protection of incumbents	(4) Administrative burden for startups
$Vulnerability_{i,s,c}$	-0.011***	-0.018***	-0.042***	-0.030***
	(0.001)	(0.002)	(0.003)	(0.003)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c$	0.011***	0.041***	0.067***	0.052***
	(0.002)	(0.003)	(0.005)	(0.005)
$Vulnerability_{i,s,c} \times Weak\ competition_{s,c}$	0.003***	0.008***	0.030***	0.009***
	(0.001)	(0.001)	(0.003)	(0.001)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c \times Weak\ competition_{s,c}$	-0.004***	-0.021***	-0.049***	-0.017***
	(0.001)	(0.002)	(0.004)	(0.002)
Observations	664,086	664,086	664,086	664,086
R-squared	0.062	0.062	0.062	0.062
Country-Sector FE	Yes	Yes	Yes	Yes

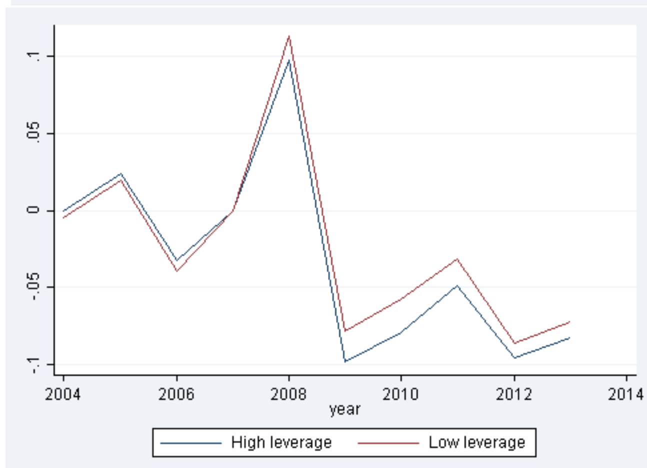
*Note: The dependent variable is the difference in the average net investment in intangible assets (as a ratio of total assets) between post- and pre-crisis periods. Firm-level Vulnerability is measured as the average debt-to-assets ratio in the pre-crisis period. Expansionary monetary conditions is the average OECD forecast error for long term (10-year government bond) interest rate in the post-crisis period as a measure of more-than-expected policy loosening. Weak competition is measured as the median markup estimate in each country-sector, reflecting the degree of profitablity in column 1; the OECD indicator of Product Market Regulation (PMR) in 2008 in column 2; the OECD indicator of Regulatory Protection of Incumbents (RPI) in 2008; the OECD indicator of Administrative Burdens for Start-ups (ABS) in 2008 in column 4. The post-crisis period starts in 2008. Firm-specific controls (included in regressions but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with Expansionary monetary conditions and/or Weak competition measures. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level.*

Table 2.7: *Further Robustness Checks*

	(1) Shorter window (2005-2010)	(2) Alternative vulnerability (interest coverage)	(3) Linear probability	(4) Excluding zeros (no intangible assets)
$Vulnerability_{i,s,c}$	-0.013***	-0.002***	-0.175***	-0.010***
	(0.001)	(0.000)	(0.013)	(0.001)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c$	0.011***	0.004***	0.078***	0.011***
	(0.002)	(0.001)	(0.023)	(0.002)
$Vulnerability_{i,s,c} \times Weak\ competition_{s,c}$	0.093***	0.012*	0.879***	0.069***
	(0.015)	(0.007)	(0.209)	(0.016)
$Vulnerability_{i,s,c} \times Expansionary\ monetary\ conditions_c \times Weak\ competition_{s,c}$	-0.100***	-0.028***	-0.623*	-0.096***
	(0.024)	(0.009)	(0.322)	(0.023)
Observations	615,143	664,453	664,086	518,048
R-squared	0.074	0.060	0.087	0.072
Country-Sector FE	Yes	Yes	Yes	Yes

*Note: The dependent variable is the difference in the average net investment in intangible assets (as a ratio of total assets) between post- and pre-crisis periods. Firm-level Vulnerability is measured as the average debt-to-assets ratio in the pre-crisis period except for in column 2 where it is measured as the interest coverage ratio (the average ratio of interest payments to earnings (EBITDA)) in the pre-crissi period. Expansionary monetary conditions is the average OECD forecast error for long term (10-year government bond) interest rate in the post-crisis period as a measure of more-than-expected policy loosening. Weak competition is measured as the median pre-crisis Lerner index value in each country-sector, reflecting the degree of profitablity. Column 1 considers a shorter window between 2005 and 2010; column 3 corresponds to linear probability model by replacing the non-negative dependent variable with 1 (and 0 otherwise). Column 4 excludes obersvations without intangible assets in both periods, and hence, no change in intangible investement during the periods. The post-crisis period starts in 2008. Firm-specific controls (included in regressions but not reported) are firm age, total assets, and cash-flow/assets ratio as well as their interaction terms with Expansionary monetary conditions and/or Weak competition measures. All columns include country-sector fixed effects. Standard errors are clustered at the country-sector level. *: significant at 10% level; **: significant at 5% level; ***: significant at 1% level.*

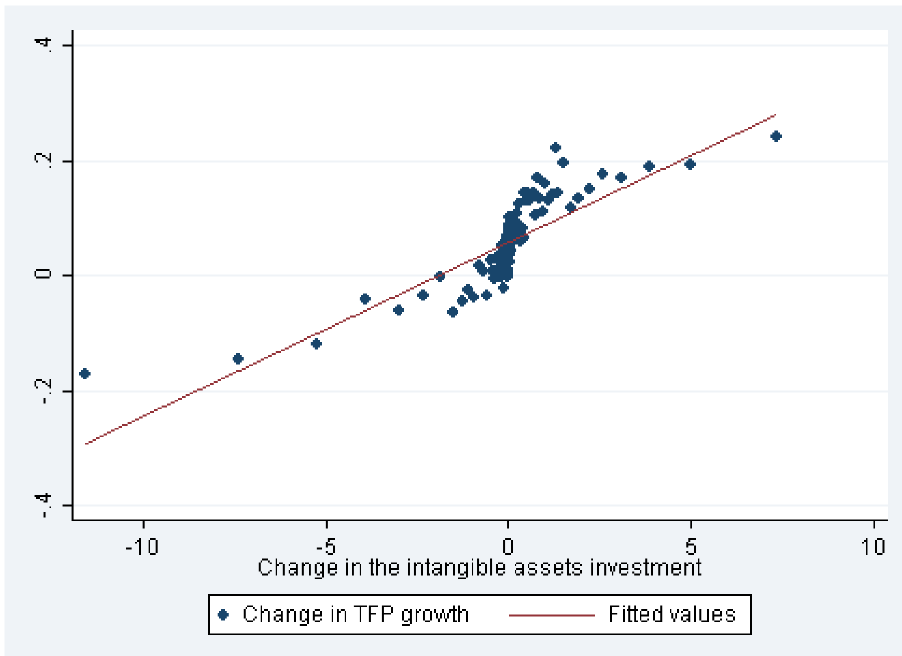
Figure 2.1: *Illustration of the Pre- and Post-GFC Trends in Intangible and Tangible Investment Growth in High-Leverage versus Low-Leverage Firms*



(1) Average intangible investment growth for high-low leverage firms
(2) Average tangible investment growth for high-low leverage firms

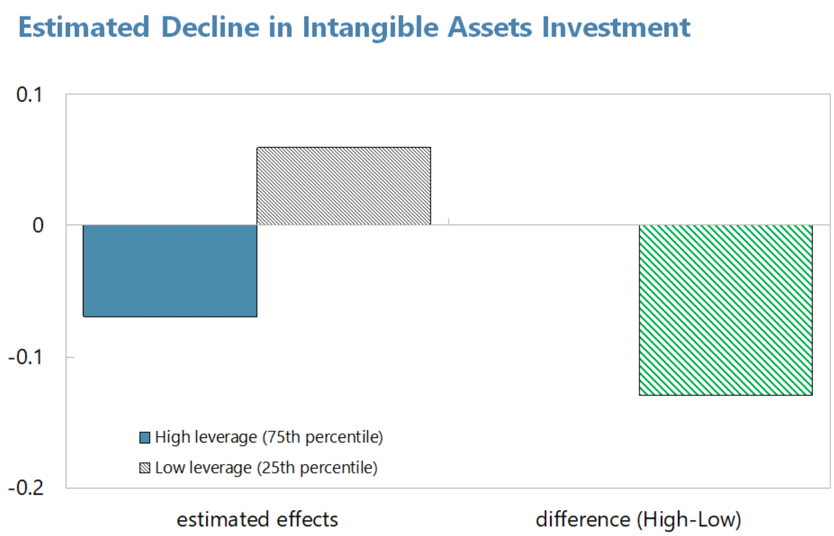
Note: This figures illustrate the evolution of average intangible (panel a) and tangible (panel b) investment growth in high-leverage versus low-leverage firms. Each series in the panel represents a coefficient estimate on year dummy variables from a regression of firm-level intangible (panel a) or tangible (panel b) investment growh on year dummies and country-sector fixed effects separately for high-leverage firms (blue solid line) and low-leverage firms (red solid line), where the leverage threshold used to split the data in two groups is, in each country-sector separately, the median across firms of the average leverage ratio over the pre-crisis period.

Figure 2.2: *Illustration of the Link between the Change in Average TFP Growth and Average Intangible Investment Growth between the Pre-GFC and post-GFC periods*



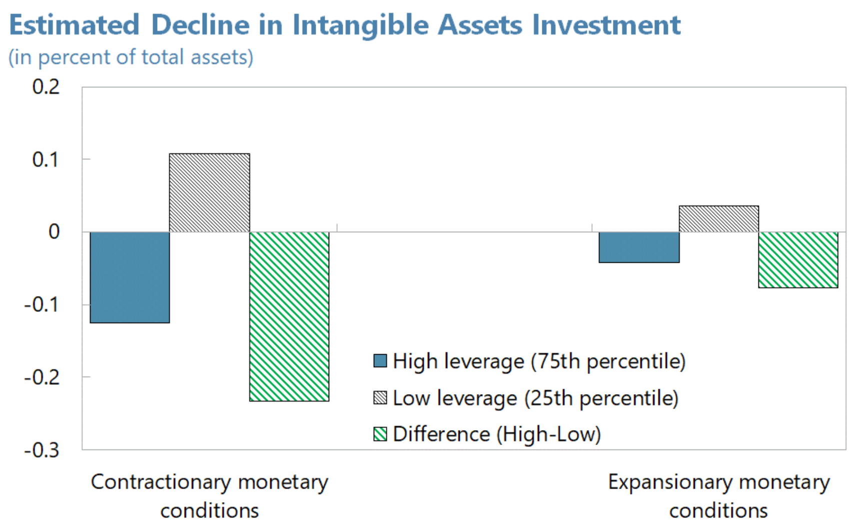
Note: For each firm in the sample, the change in the intangible-to-total-assets ratio (in percent) between the pre- and post-crisis periods is calculated, and then ranked. The resulting data are then broken into 100 quantiles, for each of which the median value of the change in the intangible-to-total-assets ratio is calculated. Each dot in the figure represents this quantile-median, as a deviation from a country-sector fixed effect (x-axis). It is plotted against the quantile-median of the deviation of the change in average TFP growth from a country-sector fixed effect (y-axis). The post- and pre-crisis periods includes five years after and before the 2008 crisis, respectively.

Figure 2.3: *Illustration of the Baseline Estimation Results: Financial Frictions and Intangible Investment*



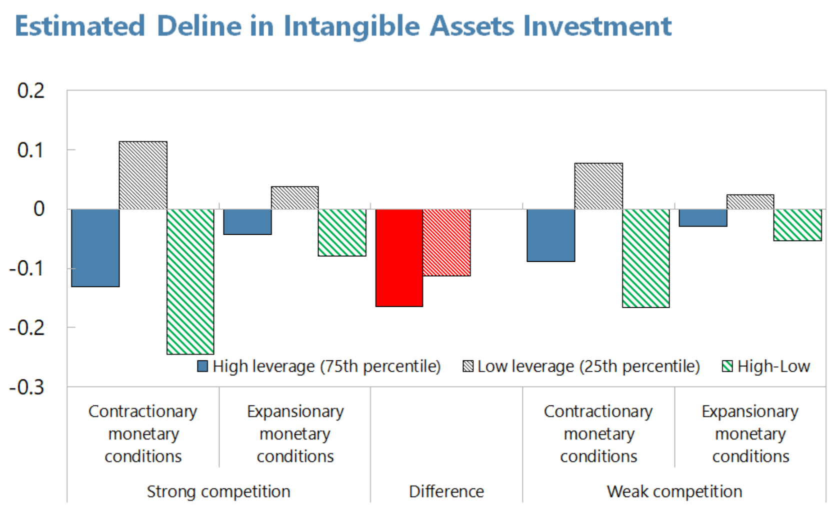
Note: High (low) leverage corresponds to the 75th (25th) percentile of the cross-firm distribution of pre-crisis average leverage ratio. The green shaded bar indicates the difference in estimated effects for high and low leverage firms. Estimated coefficients are from column (1) in the baseline results table.

Figure 2.4: *Illustration of the Baseline Estimation Results: The Role of Countercyclical Policy*



Note: High (low) leverage corresponds to the 75th (25th) percentile of the cross-firm distribution of pre-crisis average leverage ratio. The green shaded bars indicate the difference in estimated effects for high and low leverage firms, separately for contractionary and expansionary monetary conditions. Estimated coefficients are from column (2) in the baseline results table. Expansionary/contractionary monetary conditions are defined as forecast errors in 10-year gov't bond yields by +/-50 bps.

Figure 2.5: *Illustration of the Baseline Estimation Results: Complementarity between Product Market Competition and Counter-cyclical Policy*



Note: High (low) leverage corresponds to the 75th (25th) percentile of the cross-firm distribution of pre-crisis average leverage ratios. The green shaded bars indicate the difference in estimated effects for high and low leverage firms in contractionary and expansionary monetary conditions, respectively, while the red bars measure the difference between them, separately for strong and weak competition environments. Estimated coefficients are from column (4) in the baseline results table. Expansionary/contractionary monetary conditions are defined as forecast errors in 10-year gov't bond yields by +/-50 bps. Weak (strong) competition corresponds to the 75th (25th) percentile of the country-sector distribution of pre-crisis average Lerner index values.

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Chapter 3: Financial Crises and Innovation

3.1 Introduction

Financial crises are associated with large declines in economic output which can persist for many years following the event (Kroszner et al. 2007, Dell'Ariccia et al. 2008, Reinhart and Rogoff 2009, Furceri and Zdzienicka 2011a, 2011b). They have been shown to lead to permanent losses in output, not just temporary slowdowns that return to the original growth path (Cerra and Saxena 2005 and 2008, Teulings and Zubanov 2014).[1] But how do financial crises affect long term growth? Is there a financial channel that serves as a mechanism for the effect? If so, is this financial channel at play in all types of financial crises? While the impacts of crises on output have been extensively studied, less emphasis has been placed on exploring the possible channels by which these events affect long term growth.[2] We study one mechanism for this transmission, which is the effect financial crises have on innovation. We show that patenting, an indicator of innovative activity, falls

[1]Cerra and Saxena (2017) suggest that permanent output loss is a wider pattern for recessions generally, though financial crises tend to result in lower economic outcome.

[2]The theoretical literature has explored how financial constraints in a model of heterogeneous firms can lead to resource misallocation (and thus a drop in TFP) during a credit crunch (Buera and Moll 2015, Gopinath et al. 2017). Queralto (2013) provides a model by which a decline in business creation (induced by frictions in financial intermediation) is the mechanism by which financial crises result in persistently low output.

following financial crises, and we identify an important financial channel at play during banking crises that drives this result.

In many growth models, technological progress is an important driver of long term growth, and this progress can be determined by investment in research and innovative activities (see Grossman and Helpman 1991, Romer 1990, Aghion and Howitt 1992). We study the effect of financial crises on patenting behavior, a measure of innovative activities, as one mechanism by which financial crises can have these long-lasting negative effects on growth. We explicitly test for a financial channel for that effect. To our knowledge, this is the first paper to study the impact of financial crises on patenting in a cross-country setting.[3] Our paper provides evidence for a causal link between financial disruptions and patenting outcomes.

R&D funding is typically more difficult to obtain than financing for other firm projects due to several reasons, such as long gestation lags, high uncertainty in the outcome, or R&D activities being nonpledgeable as collateral. Thus, we expect innovative activity to be more sensitive to disruptions in financial markets, with potentially important consequences. Our financial channel for crises and innovation works as follows: Firms may fund long term investment, such as investments that focus on innovation (and may result in a patent), using external financing. When firms lose access to external finance (such as via a financial crisis or other shock), they will be less able to make those long term investments and consequently their

[3] OECD (2012) presents country-level data for OECD countries for patenting and other measures of innovation around the global financial crisis. It does not directly test for the impact of financial crises on patenting. Markatou and Vetsikas (2015) and Queralto (2013) provide country level analysis for Greece and Korea, respectively. Nanda and Nicholas (2014) provides evidence for banking distress on patenting, but only for the case of early 20th century US.

patenting may decline in the coming periods. This mechanism will be stronger the more reliant firms are on external finance. Thus, for large disruptions in credit markets that occur with financial crises, we would expect patenting to drop in the years following the event (reflecting the time lag from investment to patentable output), and a larger drop for firms in sectors that are more dependent on external finance. We perform our analysis using sector level data on patenting from NBER's patent database. Our sample covers 32 countries with 51 financial crises over 1976-2006.

We take two approaches to study the effect of financial crises and recessions on patenting. In order to identify the financial channel, we first employ fixed effect panel regressions. We compare sectors which rely more on external finance with those that are less reliant, à la Rajan and Zingales (1998), in a difference-in-differences approach. We control for country-year fixed effects to account for the common shocks that may affect all firms in a country when they experience a crisis. We also control for country-sector fixed effects to account for level differences in the growth rate of patenting done by a particular sector in a particular country. We further check that our results are robust to alternative explanations (recessions that accompany crises, changes in trade, reverse causality etc.) to confirm our identification. Our second approach examines impulse response functions (IRFs) by implementing a Local Projection Method (LPM). This allows us to estimate the dynamic response and persistence of the impact in a flexible way. Here, we again test if the differential response of sectors dependent on external finance following a crisis event.

Our results document that aggregate patent growth is lower (negative) following a financial crisis in the country. Controlling for country and year fixed effects, we find that patent growth is on average -2.5% in the 4 years following a financial crisis, whereas it is 0.5% if there was no crisis in the past 4 years. Patenting growth is much lower for the most financially dependent sectors as compared to the least dependent sectors.

Using our panel regressions, we identify a financial channel and find a large drop in patenting for financially dependent sectors following a financial crisis relative to non-dependent sectors. Sectors at the 75th percentile of the financial dependence distribution have patent growth that is 3-5 percentage points lower than sectors at 25th percentile for the 4 years following a financial crisis. We show that these results are driven by banking crises, and not currency or sovereign debt crises. We further illustrate that these results are not driven by recessions generally, which may accompany a crisis; recessions can have a general negative effect, but do not differentially affect financially dependent sectors.[4] We examine if individual patent quality, measured by citations per patent, also drops following the banking crisis. While the quantity of patents, as well as the overall quality (measured by total citations), drops for financially dependent sectors, we find that the average patent quality does not differentially change for sectors dependent on external finance and other sectors.

Examining the persistence of these effects, we find that for banking crises,

[4]In a few specifications, there is a negative effect for financially dependent sectors that is statistically significant in the 4th year following the recession event.

the negative impact on financially dependent sectors can last upwards of 10 years. This suggests that firms which lose access to finance to not simply delay the implementation of these projects, which would result in faster growth later on, but rather they might abandon or liquidate such projects prematurely due to the financial constraints that they face. For currency and sovereign debt crises, we again find no significant response for sectors that are more dependent on external finance. Thus, our results suggest that there is a banking channel that affects patenting with long-lasting effects, implying long-lasting effects on growth via decreased innovation. This implies an important role for financing generally and banks specifically in determining long term investment and growth. Our work suggests that policy makers have additional incentives to pursue strategies that minimize the probability of a crisis, perhaps at the expense of higher short term growth. In the event of a crisis, restoring access to finance, perhaps targeted at R&D investments, may be worthile to help speed the recovery.

3.1.1 Literature

We contribute to the extensive literature on the real effects of financial crises, particularly the empirical literature on crises and growth. This literature has found that financial crises are associated with large and persistent economic losses (Cerra and Saxena 2005, 2008, Reinhart and Rogoff 2009, Furceri and Zdzienicka 2011a). In large cross-country studies, Cerra and Saxena (2008) show that output losses following banking and currency crises are very persistent, while Furceri and Zdzienicka

(2011b) provide similar evidence in the case of sovereign debt crises. Teulings and Zubanov (2014) find that economic recovery following banking crises is slow and prolonged, rather than a sharp return to the original growth path. These studies suggest that the effects of financial crises take a long term and possibly permanent toll on the economy. Our work provides evidence for one mechanism by which financial crises can have such long-lasting negative effects. Dell'Ariccia et al. (2008) and Kroszner et al. (2007) provide evidence that sectors that are more dependent on external finance grow slower than others following a banking crisis. We take this a step further to examine one reason why their growth is slower and also explain the persistence of such shocks.

Our study also relates closely to the recent literature on finance and innovation. Hsu et al. (2014) and Bravo-Biosca (2007) examine how the development of debt and equity markets affects patenting behavior. Most closely aligned with our work is Nanda and Nicholas (2014). They show, using firm level data from the US, that patenting volume and quality decreased for research firms which were in locations with higher levels of banking distress during the Great Depression. We show that this relationship is systematic across countries, as banking crises specifically affect firms that are more dependent on access to external finance, and that the effects are long-lasting.

A large theoretical literature has studied the relationship between innovation and growth broadly (e.g. Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992) as well as innovation and firm dynamics (Caballero and Engel 1993, Kletter and Kortum 2004, Lentz and Mortensen 2008, Garcia-Macia et al. 2016).

While these models are plausible and seek to fit the aggregate facts, few empirical papers have been able to identify the effect of innovation on growth. Kogan et al. (2017) is an important empirical contribution. They construct a new measure of patent value at the patent level, and use that to construct an aggregate innovation index to measure of the value of patents and patenting activities in the economy. Their results indicate that innovation accounts for significant medium run fluctuations in aggregate growth. We contribute to this literature by providing evidence for a link between financing and patenting activities as a mechanism to explain the growth effects following financial crises.

Lastly, our paper contributes to the literature on finance and growth. Numerous empirical papers have found strong correlations between finance and growth Goldsnith 1969, McKinnon 1973, King and Levine 1993),[5] with several suggesting evidence that better access to finance (via more developed financial systems and markets) have a positive causal impact on growth (Jayaratne and Strahan 1996, Levine 1999, Beck and Levine 2004). Rajan and Zingales (1998) show that sectors which are more dependent on external finance grow faster in countries which have more developed financial markets. An important contribution is from Beck et al. (2000) who suggest that financial development affects economic growth primarily through its impact on TFP and not through capital allocation or savings rates. We provide crucial evidence for this literature for an important mechanism, financing for innovative activities, by which finance may have causal effects on economic growth.

[5] Schumpeter, in his classical analysis (The Theory of Economic Development), suggested this link between finance and growth, indeed setting the intellectual stage, along with his other work, for the interplay of finance, innovation, and growth.

The remainder of this paper consists of a description of our data and methodology in Section 3.2, a description of our empirical methodology in Section 3.3, a presentation and analysis of our results in Section 3.4, and concluding remarks in Section 3.5.

3.2 Data

3.2.1 Financial crises, recessions and other macroeconomic variables

The events in our study include recession and financial crisis episodes, where financial crises include banking, currency, and sovereign debt crises. We adopt dates for financial crises from Laeven and Valencia (2012) who create the most commonly used database on worldwide crisis event dates. An event is identified as the starting date of a systemic banking crisis if there are significant signals of financial distress in the banking system and there is a significant intervention of policy in banking in a country at a given year. Currency crisis events are indicated when there is a nominal depreciation of more than 30 percent vis-à-vis the US dollar and which is at least 10 percent higher than the depreciation in the previous year. Debt crises are defined as years when a sovereign debt default occurs. We define a dummy for each sort of financial crisis which takes a value of 1 whenever the specific crisis takes place. Financial crises are often accompanied by recessions. Thus, we want to examine if the effects we are capturing are really just the result of recessions or if they are specific to financial crises. We define a recession as a dummy equal to 1 when real GDP growth is negative and 0 otherwise (as in Cerra et al. 2013).

We use the following macroeconomic indicators from the World Bank's World Development Indicators (WDI) database: real GDP per capita in constant in 2010 US dollars (as a measure of the level of economic development), gross trade (imports + exports) to GDP ratio (as a proxy for trade openness), and exports to GDP ratio (as a proxy for foreign demand). We additionaly use a measure of institutional quality from the Polity IV dataset.[6]

3.2.2 Industry level data

3.2.2.1 Innovation

The extant literature on innovation has used patent data as a measure of cross-country innovative outcomes (Griffith et al. 2006, Acharya and Subramanian 2009, Hsu et al. 2014). Due to the territorial principle in patenting laws in the US, anyone claiming exclusive rights for an invention is required to file US patents. Since the US is the largest technology consumption market in the world, and has been for a long time, we make the standard assumption that potentially important inventions from all countries have been patented in the US.

We use NBER patent database that contains detailed information of all patent applications under USPTO over 1976-2006 at annual basis. The NBER patent database is available online[7] and consists of detailed patent and citation information, such as the patent application year, grant year, the identity of assignees, a three-

[6] Following the literature, e.g. Acemoglu et al. (2003), we use the degree of institutional constraints placed on executive power as a proxy for institutional quality.

[7] Available at https://sites.google.com/site/patentdataproject/Home

digit technology class, the number of citations, and a weighting factor for citations (described in more detail below). We exclude patents filed by governments because their patents are less likely driven by financial market development Bravo-Biosca (2007).[8]

We construct 3 different measures for innovative activities. First, we use number of patent applications in 2 digit manufacturing sectors (SIC 20-39). In keeping with the literature, we calculate country-sector level patents in a given year using the application year instead of its grant year. The logic behind this choice is that the application year captures the actual time of innovation better than the grant year due to delays in the procedure.

Although total number of patents is a straightforward and intuitive measure, one concern about it proxying for innovative outcomes may be that it does not capture how important a patent is. To address this concern, our second measure uses the number of citations received by patents in a given country-sector with applications submitted in a given year, as a proxy for the value of innovative outcome (see also Trajantenberg 1990, Harhoff et al. 1999, Aghion et al. 2013). More citations indicate a higher market value of the innovative output, as many other innovations (patents) use and make reference to it. Since patents can receive citations beyond 2006 when the data ends, a simple count of citations is subject to truncation bias. To correct for this, we adjust the number of citations by using the weighting factor in the NBER patent database.[9] This weighting factor was constructed in Hall et al.

[8]Patents from government are a very small share of overall patents, especially so for non-US governments. Our results however are robust to their inclusion.

[9]This follows the literature. See for example Hsu et al. (2014).

(2001), who estimate the shape of the citation-lag distribution.

Finally, we are concerned with whether crises affect the quality of individual patents as a complement to the picture given by the change in quantity. To examine this, we compute a measure of average patent quality for a given country-sector-year by dividing the total number of (weighting corrected) citations by the total number of patents in the given country-sector-year in which they were applied. While imperfect, this provides a measure of the importance and influence of the average patent, which can serve to indicate the general quality of individual patents applied.

It is not a trivial task to assign US patents to corresponding SIC industry codes, since the USPTO does not require patent applicants and examiners to provide SIC codes in patent documents. As an alternative, the USPTO uses a 3-digit technology class system that assigns patents to a technology classification. To address this problem, Hsu et al. (2014) propose an approach, based on Kortum and Putnam (1997) and Silverman (2003), by leveraging the distribution of US listed firms' patent classes. Hsu et al. (2014) identify patents owned by listed firms in Compustat and then link the patent's technology classes to firms' SIC codes in Compustat using a weighting scheme.[10] We follow the same procedure to map patents in the NBER database to 2-digit SIC codes.[11]

[10]The NBER patent database includes Compustat identifiers.

[11]We thank Po-Hsuan Hsu for providing the weights and concordance table on his website.

3.2.2.2 External dependence, high tech intensiveness, and value added

For each sector, we compute the degree to which that sector is dependent on external finance to fund its operations, as in Rajan and Zingales (1998). We construct this for each industry using firm-level data in COMPUSTAT for US listed firms, and use the measure across all countries.[12] To calculate a sector's dependence on external finance in a given year, we use the median of firm dependence in that sector in that year. Finally, to get the external dependence of an industry over 1976-2006, we calculate the time series median of each sector's external dependence finance during the period. Thus, the typical firm in an industry with higher external dependence uses more external finance to fund its investment in both capital and R&D.

For our identification to hold, there are 2 implicit assumptions which are now standard in the literature using the Rajan-Zingales approach. First, we assume that there is a technological reason which drives that some industries are more dependent on external finance than others (e.g. gestation lags, initial investment scale). Second, we assume that these technological differences hold across countries, such that we can use an industry's dependence on external finance calculated using the data on firms in the US as a proxy for its dependence on external finance in other countries.

Hsu et al. (2014) find that high-tech intensive sectors, which may undertake

[12] External financial dependence for a firm is calculated as capital expenditures plus R&D expenses minus cash flows from operations, all divided by the sum of capital expenditures and R&D expenses. We define cash flows from operations as funds from operations plus decreases in inventories, decreases in receivables, and increases in payables.

relatively more risky and innovative projects, are more innovative in countries that have more developed equity markets. We similarly construct a measure of high-tech intensity to see if high-tech sectors are disproportionately affected in their patenting activity by financial crises.[13]

An important control we include is the value added share of the sector in total manufacturing value added for its country in a given year. As a sector becomes relatively larger and more important to the economy, we may expect it to devote relatively more resources to innovation. We use UNIDO industry level dataset to construct this variable.[14]

3.2.3 Sample

Our sample covers 32 economies including both developing, emerging market and developed economies: Argentina, Australia, Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Hungary, India, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Malaysia, Mexico, Netherlands, New Zealand, Norway, Poland, Russia, Singapore, South Africa, Spain, Sweden, Switzerland, the UK, and the US. This sample and the time period, 1976-2006, is restricted by data availability in the NBER patent database. As in Hsu et al. (2014), we drop Czechoslovakia as it divided into two countries during the sample period, China and Hong Kong, which are not in the UNIDO database and so we cannot control for their value added

[13]This measure is constructed by calculating the time series median of each sector's annual gross growth in R&D expenses during the period 19762006, and then defining high-tech intensive sectors as those whose figure is above the cross-section median in this measure.

[14]UNIDO dataset is based on ISIC Rev 3. Codes. We use a concordance table to map those to SIC codes, available at http://unstats.un.org/unsd/cr/registry/regdnld.asp?Lg=1

share, and Taiwan which does not have WDI data to use for controls.

Table 1 provides the dates for financial crises in our sample. We observe that 17 countries faced 22 events of banking crises, 12 countries had 22 events of currency crises, and only 6 countries experienced 7 events of debt crises. In total, there are 18 countries that had any kind of financial crisis at least once and there are 51 events of financial crises, and these crises were experienced by advanced economies as well as emerging markets and other developing countries. Also, there are 26 countries in our sample that experienced 68 events of recessions.

3.2.4 Summary statistics

Table 3.2 lists the sector breakdown and their respective measures of financial dependence and high tech intensiveness. Table 3 summarizes our outcome variables.

3.3 Methodology

3.3.1 Baseline specification

We ask whether financial crises have a negative impact on patenting in sectors, particularly if a sector is more dependent on external finance. We explore this first in a panel regression. The dependent variable $Innovation_{i,j,t}$ is the log of 1 plus number of patents in country i and sector j at year t. Our alternative dependent variables using citations are defined as log of 1 plus the number of (weighted) citations, an alternative measure of patent output, and citations per patent. Citations per patent is a measure of the quality of an average patent filed by each country-sector in each year. We calculate this by dividing weighted number of total citations by total number of patents. We have interaction between industry j's dependence on external finance and dummies for all 3 types of financial crises to isolate the impact of each specific crisis type. We use 4 lags of these variables allowing possible delays in the impact of crises on innovative outcomes.[15]

We control for lag value added share of industry j in country's total value added of manufacturing. We also include country-sector ($\theta_{i,j}$) and country-time ($\theta_{i,t}$) fixed effects. These sets of fixed effects are crucial for our identification. $\theta_{i,t}$ absorbs shocks to a given country at a given year, which captures the common effect that the crisis or recession may have on the economy. Thus, we are identifying the financial channel based on comparing sectors that differ in their external financial dependence, but are in the same country at the same time. $\theta_{i,j}$ accounts for unobserved characteristics of each sector in each country, to account for how some financially dependent sectors may patent at different rates in different countries. Standard errors are clustered at industry-time level, accounting for any correlation in the errors common to industries across countries each year.[16] Our regression specification is thus as follows:

$$\begin{aligned} Innovation_{i,j,t} &= \alpha_1 VA_{i,j,t-1} + \sum_{k=1}^{4} \alpha_{2,k} Dependence_j \times Bank_{i,t-k} \\ &+ \sum_{k=1}^{4} \alpha_{3,k} Dependence_j \times Currency_{i,t-k} \\ &+ \sum_{k=1}^{4} \alpha_{4,k} Dependence_j \times Debt_{i,t-k} + \theta_{i,j} + \theta_{i,t} + \epsilon_{i,j,t} \end{aligned} \tag{3.1}$$

[15]We consider longer time horizons in our second empirical approach.

[16]Results are robust to clustering at different levels, including a more conservative triple cluster at the sector, country, and time levels. However, the low number of clusters along each dimension make the asymptotic properties of the estimator less likely to hold, so it is not our preferred specification.

We extend this setup to also include $Recession_{i,t-k}$ and its interaction with $Dependence_j$. In robustness, we include interactions of additional macroeconomic variables (with 4 lags) with $Dependence_j$ to confirm that other concurrent macroeconomic developments are not driving the relationship. Note that the direct effects of financial dependence and of each form of crisis or recession are absorbed by our fixed effects.

With this setup, we are implicitly using a difference-in-differences design. Thus, our identification rests on the assumption that sectors dependent on external finance do not have different pre-crisis trends than other sectors, after our fixed effects and other controls have been accounted for. We validate our approach in Section 3.4.6.

3.3.2 Persistence of effects

In order to explore whether the negative impact of crises on patenting is long-lasting, we employ an alternative specification proposed by Teulings and Zubanov (2014), based on the local projections method (LPM) by Jorda (2005). This method allows us to generate an impulse response to each crisis/recession in a flexible way, respecting our specification and fixed effects. Teulings and Zubanov (2014) illustrate that standard LPM is biased when examining the effects of crisis events, but including future values for crises corrects for this bias.[17] Hence, our specification to examine persistence is as follows:

[17] We note that including the lagged dependent variable and fixed effects may still lead to a bias the estimation in small samples (e.g. Nickell 1981). However, the length of the time dimension ameliorates this concern. Teulings and Zubanov (2014) illustrate that this sort of bias essentially disappears, if number of years is greater than 30.

$$
\begin{aligned}
Innovation_{i,j,t+p} &= \sum_{k=1}^{4} \beta_1^k Innovation_{i,j,t-k} + \sum_{k=1}^{4} \beta_2^k VA_{i,j,t-k} \\
&+ \sum_{k=0}^{4} \beta_{3,1}^k Dependence_j \times Bank_{i,t-k} + \sum_{l=0}^{p-1} \beta_{3,2}^l Dependence_j \times Bank_{i,t+p-l} \\
&+ \sum_{k=0}^{4} \beta_{4,1}^k Dependence_j \times Currency_{i,t-k} + \sum_{l=0}^{p-1} \beta_{4,2}^l Dependence_j \times Currency_{i,t+p-l} \\
&+ \sum_{k=0}^{4} \beta_{5,1}^k Dependence_j \times Debt_{i,t-k} + \sum_{l=0}^{p-1} \beta_{5,2}^l Dependence_j \times Debt_{i,t+p-l} \\
&+\theta_{i,j} + \theta_{i,t} + \epsilon_{i,j,t} \qquad (3.2)
\end{aligned}
$$

We estimate 3.2 for 10 periods following each event ($p = 1, ...10$) which allows us to see the evolution of the impact over a longer period of time. We report the coefficient estimates with a 90 percent confidence interval.

3.4 Results

3.4.1 Aggregate patenting

We first illustrate that there is a systematic relationship between crises and patenting activity at the aggregate level. We regress growth rate of aggregate patenting on country and year fixed effects, to account for country specific differences and common shocks, and obtain the residual growth. We then calculate the mean residual growth if there is a sort of financial crisis within the past four years and the mean residual growth if there was no crisis within the past four years. Figure 3.1 displays these averages.

Panel (a) shows that the residual growth of patenting is around -2.5% on average in 4-year period following a sort of financial crisis, whereas it is around 0.5% if there was no crisis in the previous 4 years. This suggests that there is a general pattern in the relationship between financial crises and patenting at the aggregate level. Panel (b) displays the average drop in patenting growth following a financial crisis for the 4 most dependent sectors and the 4 least dependent sectors. The most financially dependent sectors have a larger drop in total patenting (3 percent), compared to the least dependent sectors (1.4 percent), suggesting that access to finance during a crisis may play a role. Thus, in the next section we formally test for this financial channel and examine its impacts in different types of financial crises.

3.4.2 Main results

In the first column of Table 3.4, we examine whether financial crises have a negative impact on innovation for financially dependent sectors, and then how this impact varies by crisis type. We include 4 lags of each crisis to allow for both an immediate and medium term impact. Column 1 shows a robust, negative relationship between financial crises and patenting growth for financially dependent firms. The negative impact is significant and persist through all 4 lags.[18]

[18] Further lags are also significant, but we present the first 4 for illustration. Impulse responses with 10 lags are considered in Section 3.4.7.

This drop is relatively large. Consider a comparison of outcomes for the 25th and 75th percentile sectors in terms of financial dependence. The difference between them in our financial dependence measure is about 0.12. Patent growth in the 75th relative to the 25th following the crisis is $-0.320 \times 0.127 = -0.041$ in the first year, so 4.1 percentage points lower. Likewise, in year 2 the growth is 3.1% lower, in year 3 it is 4.5% lower, and in year 4 it is 5.4% lower. Compared to the average patent growth rate when there was no crisis within 4 years (0.5%), the more financially dependent firms perform significantly worse for several years following a financial crisis.

In columns 2-4, we split financial crises by type and consider them separately. Here, we see that the negative effect on financially dependent firms following a financial crisis is driven by banking crisis episodes. Indeed, the coefficients in column 2 are much larger than those in column 1. Many crises happen together and reinforce each other, such as the "twin crises" of banking and currency crises, Kaminsky and Reinhart (1999). Thus, to make sure we isolate the effect of each crisis from the others, column 5 includes all 3 types of crises at the same time. We see again that it is banking crises that drive the effect. Comparing again the 25th and 75th percentile sectors in terms of financial dependence, the 75th percentile firms have patent growth that is 6.5 percentage points lower in the first year following a banking crisis, 4.5% lower in the second, 7.6% lower in the third, and 8.6% lower in the fourth. These results are evidence for a financial channel whereby firms that are in need of external finance reduce their innovative activities (and consequently future patent output) specifically when access to that finance is disrupted, as in a banking crisis.

3.4.3 Citations

Table 3.5 examines these effects using citation growth and citations per patent. The first two columns examine our main results using log citations as the dependent variable, which captures the influence of patents produced in each period as a measure of innovative output. We find that the story is the same. Financial crises generate a negative impact on innovative output for financially dependent firms relative to other firms, and this effect is driven entirely by banking crises. Compared to the 25th percentile sector for financial dependence, the 75th sector has citation growth that is 17.8 percentage points lower in the first year following a banking crisis, 9.6% lower in the second year, 13.0% lower in the third, and 18.4% lower in the fourth. Thus, the growth in the value contribution of innovations for financially dependent sectors is significantly lower and remains so for years following the banking crisis.

Columns 3 and 4 examine how the average quality of patents change following the crisis, measured by citations per patent at the sector level. It could be the case that the number of patents drops, but the patents that remain are of higher quality.[19] This would indicate that crises may affect the quality of ideas that are pursued, specifically for financially dependent firms, and would thus signal that financially dependent firms are different along some other dimension (e.g. research quality) or that some other channel may be at play. However, we find that this is not the case. The average patent quality for financially dependent firms does not

[19] This idea is similar to Ates and Saffie (2016), who show that recessions result in fewer firms, but those firms are more productive on average.

drop relative to other firms following any of the financial crises. Thus, it appears that crises do not erode the average quality of ideas for firms, but rather affects the firm's ability to finance and carry out those ideas. This reinforces the role of a financial channel affecting innovation, and further highlights that the decrease in patenting may not be "cleansing" of lower quality patents, but rather reflects a real loss of innovative output.

3.4.4 Recessions

Many crises are typically accompanied by recessions. Recessions can generally affect innovative activities by depressing the demand, reducing credit supply, or otherwise altering the macroeconomic environment that feeds into firm decisions for investment. Thus, it is not clear if the effects we show are truly driven by a financial channel in whole or part. In Table 3.6, explore whether recessions explain our crisis results and if our financial channel is operative during recessions generally.

In general, recessions may have a negative but not significant effect on financially dependent sectors relative to other sectors. Significant impacts can be seen in the fourth lag, suggesting that there is indeed some delayed impact via our financial channel. However, across all specifications, our results for financial crises, and banking crises more specifically, are robust. Thus while recessions can generate a general negative shock to patenting activities and possibly specific shock to financially dependent sectors, our financial channel is operative primarily during banking crises and is not explained by the accompanying recession.

3.4.5 Robustness

In this section, we examine threats to our identification strategy and address potential concerns about omitted variables, sample selection, and reverse causality. In columns 1-5 of Table 3.7, we include several macroeconomic variables that may affect sector patenting. For each macroeconomic variable, we include 4 lags of the variable interacted with sector level external dependence. The column header indicates which variable is included, though for space we don't display their coefficients.

We include real GDP per capita to account for real growth in the economy which, like recessions, may afffect the macroeconomic environment in a way that changes patenting outcomes. Similarly, we include the gross trade to GDP ratio and exports to GDP ratio, as increasing trade and trade openness may differentially benefit some sectors both in terms of demand but also in terms of access to markets which makes filing a patent in the US more valuable. We also include our measure of institutional quality, as shifts in the institutional environment may occur around crises and may spur more or less patenting, with benefits potentially falling unevenly on sectors that are more or less connected to government. After including these competing interactions separately or together, our findings remain the same. Our financial channel is robust and is driven by banking crises.

Another concern is that financially dependent sectors may be different along some other dimension that drives these results. Many high-tech sectors rely on external funding to finance their investments, and they participate heavily in R&D activities. Thus, we include competing interactions of all crisis types with our high-tech sector dummy in column 6, and our results remain.

In the columns 7 and 8, we address concerns about our sample. As could be seen in Table 3.1, there are countries in our sample that did not have a financial crisis during our sample time frame. These countries may not be ideal control groups against which to compare results from countries that did experience some sort of financial crisis. Thus in column 7, we restrict our sample to just countries that have experienced at least one crisis. Banking crises remain significant in all 4 lags, while currency and debt crises are largely not significant.

Since the patent data comes from filings in the US, and the US is an enormous outlier in terms of patent volume, patenting activities of sectors in the US may not be comparable to other countries in our data.[20] Column 8 excludes the US, and our results remain the same.

Lastly, column 9 keeps only smaller sectors in each country. Some countries have very large sectors that are not atomistic and can drive both crisis events and patenting activity. To address this issue, we follow Rajan and Zingales (1998) and drop large sectors from our analysis. Large sectors are defined as those with value added above their country mean. Comparing then the smaller sectors which are less likely to directly control aggregate performance, our results remain robust. We conclude that our result is not likely to be driven by reverse causality.

3.4.6 Validation of empirical approach

Another concern with our specification may be about the pre-crisis trends in patenting, as the difference-in-differences design rests on this assumption. For instance, if sectors that are not dependent on external finance have a positive trend of patent growth, but dependent sectors have no trend, then our estimator will pick up the negative effects that we see even though the crisis had no effect. More practically, many financial crises are preceded by credit booms, which may differentially affect the patenting activities of dependent and non-dependent sectors before the crisis. Thus, we examine whether pre-crisis trends are significantly different across sectors to justify our identification strategy.

To validate this, we examine the pre-crisis leads before banking crises, the driver of our results, to see if there is any difference between dependent and non-dependent sectors in the 4 years leading up to the crisis. This setup allows us to maintain the fixed effects that are important for our identification and illustrate the pre-crisis trends in a flexible way. Figure 3.2 reports the coefficient estimates of 4 leads and 4 lags of the interaction term between banking crisis and sector level external dependence, with 90 percent confidence interval. As we see, the point estimate is around zero and insignificant until the year of crisis ($t = 0$), but becomes negative and significant following the crisis ($t > 0$). Thus, we conclude that our empirical approach and identification are valid for testing for the financial channel of innovation.

[20]Our external finance measure is based on the firms in the US, so their activities that determine financial dependence may not be exogenous to patenting activities of these firms over the sample.

3.4.7 Persistence of effects

The effects on output of crises can be very long-lasting. However, it could be the case that firms may delay projects when they lose access to external finance, only to reimplement them later. If this were the case, we would expect to see a relative decline in patent growth for dependent firms in the firs few years of a crisis, followed by a rebound with relatively higher patent growth as these "shelved" projects are redeployed. Here, we formally examine impulse response functions (using the local projection method) to the crisis events to examine the long term impact on patenting using our second empirical approach. In addition to examining the evolution of the patenting response to the crisis in a flexible way over a long horizon, this also serves as additional robustness to our earlier results.

In Figure 3.3, we report the point estimates from LPM in (2) with 90 percent confidence intervals following each sort of crisis. Panel (a) shows that banking crises have a significant negative impact on patenting, lasting 10 years or more beyond the crisis. This is important as there is not a delayed recovery whereby sectors "catch up" after the immediate crisis has abated. Thus, it does not appear that firms which lose access to finance simply delay the rollout of projects which may result in patents until after the crisis (which would result in catch-up growth), but these projects may not be launched at all (a permanent loss). These results are in line with Cerra and Saxena (2008, 2017) and Teulings and Zubanov (2014) who suggest that recoveries do not converge to the original growth path.

Confirming our previous results, panels (b) and (c) show that debt and currency crises do not have a significant impact. Thus, the role of banks appears to be important for understanding the long term relationship between finance and innovation. The long-lasting impact following banking crises illustrates the strength of the financial channel that we identify, its importance, and provides some insight into the relationship between finance and firm decision making for investment in innovation. A disruption in access to finance can prevent firms from undertaking new innovative investments, and may prevent firms from being able to conclude existing R&D projects by forcing them to liquidate assets prematurely. Due to potentially long gestation times for some projects, the impact of a crisis may be felt for many years following the event. The duration of the negative impact on innovation helps to explain the persistent and permanent output loss that we see following banking crises.

3.5 Conclusion

We examine the impact of financial crises on patenting activity. We find that patenting is lower following a financial crisis. We identify a financial channel that is at play during banking crises, whereby sectors that are more dependent on external finance patent less following a banking crisis than less dependent sectors. Patent growth remains significantly lower for these sectors for 10 years or more following a banking crisis. Our results are not driven by recessions, sample selection, reverse causality, or other macroeconomic factors correlated with financial crises. While patent quantity and overall quality declines, average patent quality (citations per patent) does not appear to be affected.

Our results provide causal evidence for an important conceptual link between financial crises and economic growth. Economic growth following financial crises appears to remain depressed for a long time, never rebounding to its original growth path. This paper shows that the effect that the crisis has on innovative activities may be an important link, as patenting falls for financially dependent sectors and remains low for over a decade following the event. The lack of catch-up growth in patenting suggests that the missing projects that never matured to produce a patent are permanently lost due to the financial shock, providing a rationale for the permanent output loss observed following crises. These outcomes suggest scope for policy makers to give larger weight to preventing a banking crisis, and for responses to a banking crisis to explicitly address investment in innovation in order to speed recovery and minimize the permanent output loss.

Our work identifies a financial channel at play during banking crises. While valuable, this mechanism appears to play a minimal role during recessions and other types of financial crises. Thus, future work should examine other channels by which these events may lead to a fall in patenting to better understand how short term macroeconomic events can affect long term innovation and macroeconomic output.

Table 3.1: *Dates for Financial Crises from Laeven and Valencia (2012)*

Country	Banking crises	Currency crises	Debt crises
Argentina	1980, 1989, 1995, 2001	1975, 1981, 1987, 2002	1982, 2001
Australia			
Austria			
Belgium			
Brazil	1990, 1994	1976, 1982, 1987, 1992, 1999	1983
Canada			
Denmark			
Finland	1991	1993	
France			
Germany			
Hungary	1991		
India	1993		
Ireland			
Israel	1977	1980, 1985	
Italy		1981	
Japan	1997		
Korea	1997	1998	
Luxembourg			
Malaysia	1997	1998	
Mexico	1981, 1994	1977, 1982, 1995	1982
Netherlands			
New Zealand	1984		
Norway	1991		
Poland	1992		1981
Russia	1998	1998	1998
Singapore			
South Africa		1984	1985
Spain	1977	1983	
Sweden	1991	1993	
Switzerland			
United Kingdom			
United States	1988		

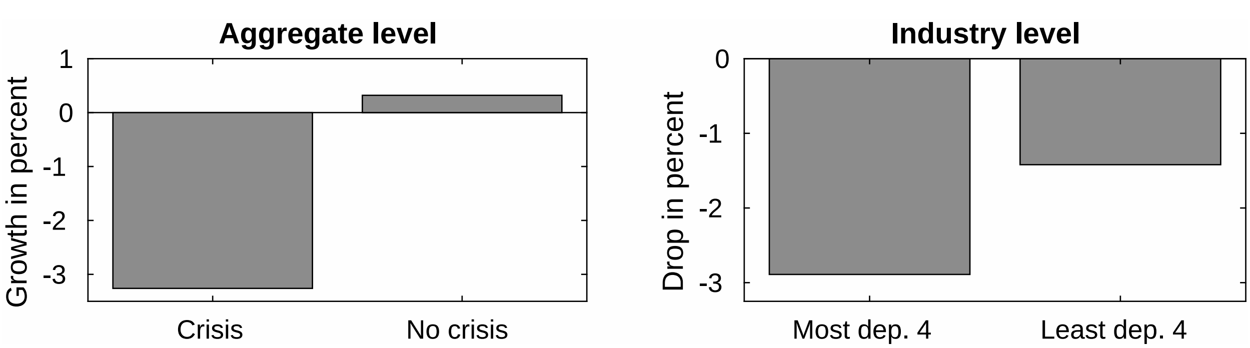

Figure 3.1: *Patent growth and financial crises*

Table 3.2: *Financial Dependence and High Tech Intensiveness across Industries*

SIC 2 Code	Industry	Dependence	High Tech
20	Food and Kindred Products	1.174	1.064
21	Tobacco Products	1.290	1.022
22	Textile Mill Products	1.131	1.048
23	Apparel and Other Finished Products Made from Fabrics and Similar Materials	1.474	1.188
24	Lumber and Wood Products, Except Furniture	1.177	1.109
25	Furniture and Fixtures	1.241	1.088
26	Paper and Allied Products	1.104	1.018
27	Printing, Publishing, and Allied Industries	1.124	1.011
28	Chemicals and Allied Products	1.028	1.120
29	Petroleum Refining and Related Industries	1.035	0.975
30	Rubber and Miscellaneous Plastics Products	1.203	1.029
31	Leather and Leather Products	1.237	1.075
32	Stone, Clay, Glass, and Concrete Products	1.102	1.062
33	Primary Metal Industries	1.203	1.014
34	Fabricated Metal Products, Except Machinery and Transportation Equipment	1.286	1.051
35	Industrial and Commercial Machinery and Computer Equipment	1.126	1.071
36	Electronic and Other Electrical Equipment and Components, except Computer Equipment	1.168	1.110
37	Transportation Equipment	1.309	1.102
38	Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks	1.205	1.098
39	Miscellaneous Manufacturing Industries	1.304	1.085

External financial dependence for a firm is calculated as capital expenditures plus R&D expenses minus cash flows from operations, all divided by the sum of capital expenditures and R&D expenses. We define cash flows from operations as funds from operations plus decreases in inventories, decreases in receivables, and increases in payables. High tech intensiveness is constructed by calculating the time series median of each sector's annual gross growth in R&D expenses during the period 19762006.

Table 3.3: *Summary Statistics for Industry Level Outcome Variables*

Variable	Mean	Median	25th percentile	75th percentile	Std dev.	Observations
Log(1+ Patents)	1.718	1.021	0.153	2.717	1.929	15 739
Log(1+Citations)	2.916	2.429	0.407	4.696	2.691	15 739
Log(1+ Citation per patent)	1.832	2.080	1.512	2.383	0.862	15 739

Patents are the total number of patents. Citations are the total number of weighted citations, where weighting factor was constructed in Hall et al. (2001) who estimate the shape of the citation-lag distribution. Citations per patent is the total number of weighted citations divided by patent counts.

Table 3.4: *Main results*

Variable	Financial crises	Banking crises	Currency crises	Debt crises	Controlling all crises
Value added share(-1)	1.753***	1.753***	1.757***	1.757***	1.751***
	(0.337)	(0.337)	(0.337)	(0.338)	(0.337)
Dependence × Financial(-1)	-0.320**				
	(0.144)				
Dependence × Financial(-2)	-0.246*				
	(0.138)				
Dependence × Financial(-3)	-0.354**				
	(0.158)				
Dependence × Financial(-4)	-0.423***				
	(0.161)				
Dependence × Banking(-1)		-0.548***			-0.517***
		(0.183)			(0.184)
Dependence × Banking(-2)		-0.384**			-0.354**
		(0.187)			(0.167)
Dependence × Banking(-3)		-0.624***			-0.599***
		(0.230)			(0.224)
Dependence × Banking(-4)		-0.730***			-0.678***
		(0.243)			(0.228)
Dependence × Currency(-1)			-0.288		-0.093
			(0.217)		(0.189)
Dependence × Currency(-2)			-0.435*		-0.233
			(0.235)		(0.212)
Dependence × Currency(-3)			-0.372		-0.226
			(0.261)		(0.246)
Dependence × Currency(-4)			-0.294		-0.331
			(0.220)		0.224
Dependence × Debt(-1)				-0.212	0.014
				(0.275)	(0.275)
Dependence × Debt(-2)				0.103	0.304
				(0.275)	(0.275)
Dependence × Debt(-3)				0.035	0.387
				(0.279)	(0.297)
Dependence × Debt(-4)				0.129	0.271
				(0.261)	(0.266)
Observations	15 739	15 739	15 739	15 739	15 739
R square	0.967	0.967	0.967	0.967	0.967

The results are based on the specification in (1). The dependent variable is the logarithm of 1 plus number of patents. Value added share is the industry's share in the total value added of the country. In the first column, we use a dummy for financial crises, which takes 1 whenever there is a sort of financial crisis. In columns 2-4, we examine the effects of individual financial crises, separately. In the last column, we control for all sorts of financial crises. Standard errors are in parentheses. Standard errors are clustered at industry-year level. $^{***}\ p < 0.01$, $^{**}\ p < 0.05$, $^{*}\ p < 0.1$.

Table 3.5: *Citations*

Variable	Citations	Citations	Citations per patent	Citations per patent
Value added share(-1)	1.225**	1.225**	-0.154	-0.152
	(0.519)	(0.519)	(0.159)	(0.159)
Dependence × Financial(-1)	-1.057***		-0.105	
	(0.236)		(0.199)	
Dependence × Financial(-2)	-0.646***		0.068	
	(0.240)		(0.151)	
Dependence × Financial(-3)	-0.826***		-0.167	
	(0.264)		(0.169)	
Dependence × Financial(-4)	-0.893***		-0.148	
	(0.264)		(0.155)	
Dependence × Banking(-1)		-1.407***		0.134
		(0.301)		(0.322)
Dependence × Banking(-2)		-0.757**		0.053
		(0.302)		(0.207)
Dependence × Banking(-3)		-1.029***		0.052
		(0.375)		(0.292)
Dependence × Banking(-4)		-1.454***		-0.440**
		(0.369)		(0.221)
Dependence × Currency(-1)		-0.546*		-0.127
		(0.319)		(0.264)
Dependence × Currency(-2)		-0.582		0.259
		(0.381)		(0.247)
Dependence × Currency(-3)		-0.303		0.261
		(0.381)		(0.247)
Dependence × Currency(-4)		-0.551		0.030
		(0.344)		(0.232)
Dependence × Debt(-1)		0.106		-0.483
		(0.531)		(0.413)
Dependence × Debt(-2)		0.132		-0.431
		(0.533)		(0.399)
Dependence × Debt(-3)		0.467		-0.340
		(0.669)		(0.581)
Dependence × Debt(-4)		0.950		-0.100
		(0.630)		(0.581)
Observations	15 739	15 739	15 739	15 739
R square	0.950	0.950	0.841	0.841

The results are based on the specification in (1). In columns 1-2, the dependent variable is the logarithm of 1 plus number of (weighted) citations. In columns 3-4, the dependent variable is the logarithm of 1 plus number of (weighted) citations divided by number of patents. Value added share is the industry's share in the total value added of the country. In the first column, we use a dummy for financial crises, which takes 1 whenever there is a sort of financial crisis. In columns 2-4, we examine the effects of individual financial crises, separately. In the last column, we control for all sorts of financial crises. Standard errors are in parentheses. Standard errors are clustered at industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.6: *Recessions*

Variable	Recessions	Financial crises	Banking crises	Currency crises	Debt crises	Controlling all types
Value added share(-1)	1.858***	1.857***	1.858***	1.858***	1.859***	1.858***
	(0.363)	(0.362)	(0.362)	(0.362)	(0.362)	(0.362)
Dependence × Recession(-1)	-0.072	-0.028	-0.003	-0.069	-0.070	0.003
	(0.148)	(0.139)	(0.137)	(0.142)	(0.149)	(0.136)
Dependence × Recession(-2)	-0.220	-0.180	-0.141	-0.201	-0.228	-0.143
	(0.147)	(0.140)	(0.139)	(0.139)	(0.149)	(0.139)
Dependence × Recession(-3)	-0.098	0.010	-0.022	-0.053	-0.100	-0.020
	(0.131)	(0.124)	(0.125)	(0.123)	(0.134)	(0.125)
Dependence × Recession(-4)	-0.287*	-0.234	-0.289*	-0.255*	-0.317**	-0.303**
	(0.153)	(0.147)	(0.152)	(0.144)	(0.156)	(0.149)
Dependence × Financial(-1)		-0.314**				
		(0.130)				
Dependence × Financial(-2)		-0.157				
		(0.121)				
Dependence × Financial(-3)		-0.352**				
		(0.146)				
Dependence × Financial(-4)		-0.405***				
		(0.141)				
Dependence × Banking(-1)			-0.633***			-0.645***
			(0.181)			(0.190)
Dependence × Banking(-2)			-0.405**			-0.440***
			(0.176)			(0.167)
Dependence × Banking(-3)			-0.673***			-0.677***
			(0.214)			(0.217)
Dependence × Banking(-4)			-0.773***			0.767***
			(0.229)			(0.223)
Dependence × Currency(-1)				-0.213		-0.073
				(0.185)		(0.175)
Dependence × Currency(-2)				-0.261		-0.093
				(0.197)		(0.192)
Dependence × Currency(-3)				-0.316		-0.191
				(0.243)		(0.233)
Dependence × Currency(-4)				-0.198		-0.254
				(0.187)		(0.192)
Dependence × Debt(-1)					0.189	0.445
					(0.326	(0.330))
Dependence × Debt(-2)					0.528	0.752**
					(0.372)	(0.378)
Dependence × Debt(-3)					0.139	0.557*
					(0.316)	(0.320)
Dependence × Debt(-4)					0.361	0.568*
					(0.314)	(0.332)
Observations	15 079	15 079	15 079	15 079	15 079	15 079
R square	0.968	0.968	0.968	0.968	0.968	0.968

The results are based on the specification in (1). The dependent variable is the logarithm of 1 plus number of patents. Value added share is the industry's share in the total value added of the country. We use a dummy for recessions, which takes 1 whenever the growth of real GDP is negative. In the first column, we test the relatonship only for recessions. In columns 2-5, we examine the effects of financial crises and individual sorts of crises, separately. In the last column, we control for all sorts of financial crises. Standard errors are in parentheses. Standard errors are clustered at industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.7: *Robustness Checks*

Variable	GDP per capita	Trade	Institutional quality	All macro variables	Export	Hightech	Subsample with financial crises	Drop US	Smaller sectors
Value added share(-1)	1.874***	1.884***	1.743***	1.874***	1.881***	1.739***	2.269***	1.785***	1.111
	(0.332)	(0.343)	(0.335)	(0.331)	(0.341)	(0.339)	(0.336)	(0.338)	(0.799)
Dependence × Banking(-1)	-0.701***	-0.572***	-0.563***	-0.693***	-0.570***	-0.595***	-0.515***	-0.518***	-0.434**
	(0.189)	(0.188)	(0.186)	(0.181)	(0.186)	(0.229)	(0.184)	(0.194)	(0.173)
Dependence × Banking(-2)	-0.609***	-0.469**	-0.447***	-0.736***	-0.439**	-0.462**	-0.346**	-0.347**	-0.334**
	(0.179)	(0.183)	(0.169)	(0.189)	(0.188)	(0.213)	(0.168)	(0.177)	(0.139)
Dependence × Banking(-3)	-0.850***	-0.655***	-0.746***	-1.077***	-0.638***	-0.824***	-0.593***	-0.614***	-0.539***
	(0.242)	(0.229)	(0.214)	(0.234)	(0.233)	(0.283)	(0.222)	(0.237)	(0.198)
Dependence × Banking(-4)	-0.929***	-0.707***	-0.777***	-1.028***	-0.695***	-0.880***	-0.676***	-0.683***	-0.424***
	(0.265)	(0.234)	(0.224)	(0.255)	(0.232)	(0.283)	(0.227)	(0.242)	(0.196)
Dependence × Currency(-1)	-0.192	-0.149	-0.027	-0.080	-0.077	-0.171	-0.100	-0.092	-0.096
	(0.185)	(0.247)	(0.195)	(0.218)	(0.246)	(0.248)	(0.188)	(0.190)	(0.151)
Dependence × Currency(-2)	-0.238	-0.267	-0.174	-0.157	-0.233	-0.443*	-0.236	-0.230	-0.226
	(0.196)	(0.238)	(0.212)	(0.204)	(0.242)	(0.267)	(0.211)	(0.212)	(0.181)
Dependence × Currency(-3)	-0.307	-0.206	-0.179	-0.258	-0.138	-0.449	-0.221	-0.223	-0.275
	(0.264)	(0.249)	(0.253)	(0.270)	(0.239)	(0.327)	(0.245)	(0.247)	(0.200)
Dependence × Currency(-4)	-0.338	-0.463**	-0.326	-0.405	-0.442	-0.548*	-0.328	-0.332	-0.455**
	(0.209)	(0.231)	(0.237)	(0.226)	(0.238)	(0.297)	(0.224)	(0.224)	(0.198)
Dependence × Debt(-1)	0.262	0.251	-0.082	-0.158	0.330	-0.164	0.024	0.014	0.116
	(0.306)	(0.315)	(0.280)	(0.342)	(0.320)	(0.373)	(0.279)	(0.277)	(0.182)
Dependence × Debt(-2)	0.611*	0.579	0.298	0.473	0.569	0.804	0.307	0.299	0.172
	(0.358)	(0.377)	(0.284)	(0.390)	(0.395)	(0.380)	(0.275)	(0.272)	(0.179)
Dependence × Debt(-3)	0.616*	0.807**	0.361	0.504	0.825	0.440	0.379	0.350	0.662***
	(0.313)	(0.323)	(0.319)	(0.366)	(0.321)	(0.403)	(0.295)	(0.297)	(0.213)
Dependence × Debt(-4)	0.430	0.574*	-0.006	0.047	0.578*	0.458	0.266	0.272	0.421*
	(0.342)	(0.339)	(0.277)	(0.389)	(0.344)	(0.366)	(0.268)	(0.267)	(0.227)
Observations	15 139	15 159	15 659	15 059	15 159	15 739	9 420	15 199	8 004
R square	0.968	0.968	0.967	0.968	0.968	0.967	0.973	0.959	0.963

The results are based on the specification in (1). The dependent variable is the logarithm of 1 plus number of patents. Value added share is the industry's share in the total value added of the country. We control for all sorts of crises in all columns. In columbs 1-3, we include interactions between industry's financial dependence and 4 lags of real GDP per capita (constant in 2010 US dollars), trade (export+import) as the ratio of GDP, and a measure of institutional quality (degree of constraints on the political executives), separately. In the fourth column, we include these 3 variables all together. In the fifth column, we include interactions between industry's financial dependence and 4 lags of export as the ratio of GDP. In the sixth column, we include interactions between industry's high tech intensiveness and 4 lags of crises. In the seventh column, we test the relationship using only the 18 countries that had at least one sort of financial crisis. In the eighth column, we drop the US from the sample. In the last column, we include only the smaller half of the industries in each country, where small sectors are defined as those with value added below their country mean over the sample period. Standard errors are in parentheses. Standard errors are clustered at industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

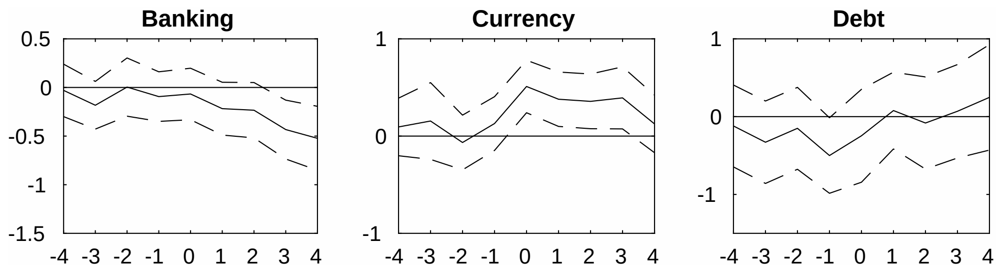

Figure 3.2: *Pre-crisis trends in patents*

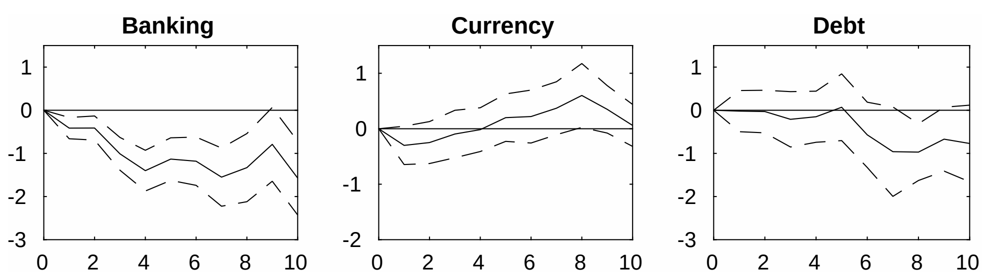

Figure 3.3: *Persistence of the effects of financial crises on patents*

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