Bank regulation, lending and patenting: Evidence from the EBA Capital Exercise*

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Abstract

We analyze the impact of decreases in available lending resources on quantitative and qualitative dimensions of firms' patenting activities. We thereby make use of the European Banking Authority?s capital exercise to carve out the causal effect of bank lending on firm innovation. In order to do so we combine various datasets to derive information on firms' financials, their patenting behaviors, as well as their relationships with their lenders. Building on this self-generated dataset, we provide support for the "less finance, less innovation" view. At the same time, we show that lower available financial resources for firms lead to improvement in the qualitative dimensions of their patents. Hence, we carve out a "less finance, less but better innovation" pattern.

Keywords: financing, bank lending, patents

JEL Classification: D22, G30, G31, G38, N24, O31, O34

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1 Introduction

Innovation constitutes a driving factor for the firm-level-productivity and economic growth (cf. King and Levine (1993)). Therefore, a better understanding of the drivers of innovation and its underlying inventions is crucial. Innovation refers to those (patented) inventions which are indeed commercially exploited (cf. Bertoni and Tykvová (2015)). The aim of this paper is to contribute to the understanding of the drivers of innovation by focusing on the link between the availability of financial resources for firms and their patenting behavior. Rather than only focusing on the quantitative dimension of patenting which only imperfectly reflects the underlying value generated by firms' innovative activities (cf. Lerner and Seru (2021)), we also investigate the effects of the availability of financial resources on the quality of firms' patents. This is guided by the idea that a simple quantitative view is not really informative if not complemented by an analysis of the qualitative effect on patents. We thereby address both the so-called "less money, less innovation " story (cf. Hottenrott and Peters (2012)) and the "less money, less but better innovation" view (cf, Hall et al. (2015)).

We aim to identify the causal link between the availability of financial resources for firms and their access to bank lending onto their patenting behavior by making use of the European Banking Authority?s (EBA) capital exercise which was introduced in 2011 as an instrument in a quasi-natural experimental setup. This capital exercise required a subset of European banks - which will be referred to as *EBA banks* - to increase their capital ratios that then reduced the availability of financial resources for the needs of firms. We show that the EBA capital exercise indeed led to less lending by the EBA banks which in turn affected the patenting activities of their corporate clients. The affected companies reacted to the reduction in the availability of financial resources by changing their patenting activities in quantitative as well as qualitative ways.

Our analysis builds on the papers that identify the importance of debt for firms' financing of innovation (cf. Kerr and Nanda (2015)) and aims to contribute to two main strands of the literature. First, we view our study as a contribution to the research on the effect of the availability of financial resources, in particular debt financing, on the innovation activities of firms (cf. Brancati (2015)). Aghion et al. (2014) find that negative financial shocks have negative effects on firms' innovativeness. Related studies analyze the effect of positive exogenous shifts in the supply of credit on innovative activities and show that financial slack promotes patenting activities in the affected firms (see Amore et al. (2013), Cornaggia et al. (2015)). Furthermore, Brown et al. (2009) find that exogenous increases in the supply of finance lead to more expenditures on R&D. Second, our study is closely related to the research that analyzes the effect of financial regulation on firms. Gropp et al. (2018) look into the effects of the EBA capital exercise and show that non-EBA banks did not substitute for the EBA banks in terms of available lending resources. Furthermore, their study discovers that firms with a high loan share at EBA banks had less growth in assets and investment (see for similar findings Mésonnier and Monks (2014)). The study closest to ours is Heller (2020) who investigate the differential consequences of staggered financial regulation on financially constrained firms versus their non-financially constrained counterparts and shows that financially constrained firms increase the number of patents but decrease their quality. We extend this analysis by investigating the effect of the lower availability of loans irrespective of the characteristics of the borrower. Furthermore, we employ a direct shock on lenders' abilities to finance firms in the course of a one-stage policy effect than than relying on an indirect, staggered mechanism based on a diverse set of policies.

Our study contributes to this literature by focusing on the effect of bank regulation which is associated with a reduction in the loans available for firms' patenting activities. Rather than focusing only on the quantitative dimension we also aim to shed light on the qualitative dimension of the patenting activities being affected by the change in bank lending. Overall, our analysis reveals potential consequences of making the banking sector more resilient. Furthermore, we stress that the relationship between financing and innovation is more complex than a less-finance, less-innovation nexus would suggest. Our study is organized as follows. In section 2, we derive hypotheses which guide our empirical analysis. In section 3, we discuss the data used in this analysis. We devote section 4 to an outline of our identification and empirical strategy. In section 5, we present the empirical results, while we conclude in section 6.

2 Hypotheses

In this section, we derive two main hypotheses that govern our empirical analysis. The literature on innovation primarily finds that in many cases firms' innovation heavily depends on external resources (cf. Fagerberg et al. (2006)). These include the availability of debt financing (see, e.g., Tykvová (2017)). Given the high degree of informational asymmetry and riskiness in innovation, studies typically have argued that firms which engage in this activity rely on equity financing. However, recent findings in the literature have shown the importance of debt for the financing of firms' innovation (Kerr and Nanda 2015). Hence, this financing means that less access to bank lending has repercussions on the intensity of patenting. Therefore, we conjecture that:

H1: A negative exogenous shock to the availability of financial resources affects the **quantitative** dimension of firms' patenting activities **negatively**.

Recent findings on US firms indicate that financial obstacles may also affect and even benefit the *qualitative* outcomes of innovation. There are a number of potential theoretical mechanisms behind this link. According to Jensen (1986), managers have incentives to grow their firms beyond optimal size, because growth increases managers' power when the resources under their control increase. This incentive may induce firms with excess funds to even invest in unproductive projects. A low availability of financial resources might imply that firms avoid such agency problems (cf. Almeida et al. (2013)). Consequently, less availability of funds might contain a disciplinary benefit which is of particular relevance because agency problems are particularly severe in innovative investments (cf. Kumar and Langberg (2009), Hall and Lerner (2010)). A second consideration is based on the idea of the decreasing returns of additional projects. A negative shock in the availability of financial resources may force firms to forgo some of their unexploited innovative projects (see Hottenrott and Peters (2012)). From the qualitative perspective, a rational firm would choose to skip those projects that appear least promising, for instance in terms of future returns. This avoidance could result in fewer realized projects but with a higher expected average quality. A third approach refers to bounded creativity considerations (see Hoegl et al. (2008)). The main idea is that constrained teams are forced to generate more creative ideas to overcompensate for the lack of financial inputs. This strand of research builds on findings from cognitive psychology (cf. Ward (1994)) according to which thinking within a frame of reference, in this case limited resources, enhances the construction of novel ideas. Further, input resource constraints could induce teams to deploy the existing set of resources more economically that thereby increases efficiency (cf. Goldenberg et al. (2001), Moreau and Dahl (2005), Gibbert and Scranton (2009)). Taking all this together, we state:

H2:*A negative exogenous shock to the availability of financial resources affects the* **qualitative** *dimensions of firms' patenting activities* **positively**

3 Empirical Strategy and Identification

Analysing the link between the availability of financial resources and the patenting activities of firms is prone to potential concerns about endogeneity and reverse causality. For instance, it might very well be that innovative firms have better access to financing. In order to overcome these concerns, we use the EBA capital exercise conducted in 2011 as a negative shock to the availability of financial resources. We then use this event in a difference-in-difference estimation setup. The EBA capital exercise provides a quasi-natural experiment in which we can control for firm-, industry-, and macro-specific variables. We use this setting to analyze how the associated shock affects innovation in terms of the different dimensions of patented inventions for those firms which are affected. The treatment is defined as the exogenous introduction of the increased capital requirements that affect a subset of European banks, while the firms' exposure to the treatment is based on ex ante differences regarding their loan shares with the EBA banks.

Heterogeneity in the sample exists in two distinct ways. First, we introduce cross-country variation by choosing the EBA banks based on their national relative market share that equals their total assets in descending order of their individual share that cover at least 50% of the respective national banking sector as of 2010. As national banking sectors differ with respect to their sizes, we disentangle the size factors by including banks from different countries with different size sectors in the capital exercise. Second, within-country variation arises from differing degrees of firms' exposure to to the treatment.

It has been shown that EBA banks substantially reduced the amount of their outstanding syndicated loans following the EBA capital exercise leading to the criticism that the exercise was contributing to a credit crunch in the euro area (cf. Degryse et al. (2021), Mésonnier and Monks (2015)). As a result, firms with a high share of loans from EBA banks have, inter alia, 4 percentage points less asset growth and 6 percentage points less investment growth[1] than firms less reliant on loans (cf. Gropp et al. (2018)). One explanation for these findings is that once the

[1]Fixed assets were used as a measure of investment, following Campello and Larrain (2015).

EBA banks decrease their amounts of outstanding loans, high switching costs make it relatively more difficult for firms to obtain new financing if they were previously more engaged with those banks. Furthermore, if the banks which were not constrained by the EBA capital exercise did not substitute for those which had to increase their capital ratios (see Gropp et al. (2018), Mésonnier and Monks (2015)), then it could explain why EBA firms were not able to obtain other sources of external funding. In line with these findings and following the related literature, the sample of firms in this paper is divided into EBA firms with an above median dependence on their credit supply from EBA banks - measured by their EBA loan share - and the non-EBA firms with a below median dependence on their credit supply from EBA banks.[2] The loan share of an individual firm j is calculated as follows:

$$\text{EBA Loan Share}_{\text{j}} = \frac{\sum_{\text{i[EBA Banks]}} \sum_{\text{q=2010 Q1}}^{\text{2010 Q4}} \text{Loans}_{\text{ijq}}}{\sum_{\text{i[All Banks]}} \sum_{\text{q=2010 Q1}}^{\text{2010 Q4}} \text{Loans}_{\text{ijq}}}$$

In the nominator, the amount of outstanding loans of firm j with EBA banks is depicted over the year preceding the EBA capital exercise. By analogy, the denominator refers to the amount of outstanding loans of firm j with all banks incorporated in European and non-European countries. EBA firms are considered as being exposed to the above-described negative impact of the EBA capital exercise on bank lending, whereas the non-EBA firms are considered as being not exposed to the EBA capital exercise. In order to address reverse causality, the firms are classified as treatment or control firms based on their individual loan shares with the EBA banks preceding the announcement of the EBA capital exercise as of 2010.

The country-specific bank selection rule of the EBA capital exercise covered 50% of each national banking sector in descending order according to each bank's market share. Therefore, the increased capital requirements from 5% to 9% can be disentangled from bank size on a cross-country basis because national banking sectors differ in size and had a considerable overlap between banks participating and not participating in the exercise (see Gropp et al. (2018)). Furthermore, endogeneity should be less of a concern, because empirical estimates in this paper are calculated on a firm-level basis, while implementation decisions of the EBA capital exercise are based on a country-bank-level (see for a similar argumentation Schnabel and Seckinger (2015)). Finally, the capital

[2] An analogous classification was conducted by Gropp et al. (2018).

exercise can be considered as being exogenous regarding i) potential preemptive adjustments of banks' balance sheets which would bias downward the effects of the capital exercise on lending, as well as regarding ii) firms' bank choices of and lending relations with certain institutions in advance of the capital exercise due to its unexpected occurrence (see Mésonnier and Monks (2015), Gropp et al. (2018)).

First, we analyze in what way the above defined exposure variable is meaningful for capturing the negative effect of the EBA capital exercise on the availability of firms' financial debt resources. We set up the following fixed-effect, cross-section regression model is set up to provide insights as to how firms' debt accounts evolve over time based on the described exposure classification:

$$Firm\ debt_{itc} = \beta_0 + \beta_1 Exp_{ic} + \beta_2 X_{itc} + \phi_{nace} + \delta_c + u_{itc} \qquad , \forall\ t \in [2007, 2014]$$

In this equation, the $Firm\ debt_{itc}$ variable measures firm i's normalized short-term bank debt at time t in firm-country c, X_{itc} resembles a vector of firm-level control variables, while ϕ_{nace} and δ_c depict industry fixed effects and country fixed effects, respectively. The exposure variable Exp_{ic} is an indicator variable which refers to the exposure classification based on their ex ante loan shares with EBA banks which is equal to one if a firm has an above median EBA loan share and zero otherwise.

Insert Figure 1 about here

Based on this regression model, figure 1 contains the regression outputs on the exposure parameter β_1 for each year between 2007 and 2014 as well as the corresponding 90% confidence intervals which are depicted by the bullets and whiskers. While the exposure coefficient estimates for β_1 are insignificant and close to zero from 2007 until 2010, the figure shows that there is a strong negative and statistically significant shift in the parameter in 2011 which also persists until 2012. This finding provides evidence that short-term bank debt did not evolve differently between the EBA and non-EBA firms from 2007 to 2010, which indicates that their bank debt was depicted by similar developments during the outbreak of the recent financial crisis. However, after the EBA capital exercise occurred, the exposure coefficient becomes significantly negative in 2011 which indicates that the amounts of short-term debt were indeed significantly lower for the EBA firms relative to the non-EBA firms. This descriptive evidence, therefore, shows that the exposure classification scheme indeed captures decreases in available financial resources for those firms with ex ante loan shares at EBA banks.

On this basis and in order to implement the identification strategy, we use a difference-in-difference approach to analyze both the quantitative and qualitative dimensions of patented inventions throughout the implementation phase of the EBA capital exercise. The panel structure of the data facilitates the controlling for not only unobserved heterogeneity across firms but also for country-fixed and time varying effects. Since borrowing generally follows a cyclical pattern (e.g., Ivashina and Scharfstein (2010)), it is particularly important to control for year-fixed-effects, that is, differences in loan conditions. Following Bertrand et al. (2004), standard errors are heteroskedasticity-consistent and clustered at the firm level. Furthermore, in order to address concerns about potentially evolving trends in the patent measures, the lagged values on the growth rates of the dependent variables are added as micro controls.

Based on these considerations, the following difference-in-difference model is constructed:

$$\begin{aligned} Patent\ Measure_{itc} = & \beta_0 + \beta_1 Exp_{ic} + \beta_2 Post_{t-1} + \beta_3 (Exp_{ic} \cdot Post_{t-1}) \\ & + \beta_4 X_{ic,t-1} + \omega_{c,t-1} + \gamma_{t-1} + u_{ict} \end{aligned}$$

where $Patent\ Measure_{itc}$ refers to different variables for *budgetary* or *qualitative* dimensions of patented inventions by firm i in period t from country c. The Exp_{ic} variable is a dummy variable that captures the exposure of firm i from country c to the treatment, that is, the EBA capital exercise. This variable equals one if the firm is from the treatment group in the respective period in time based on the ex ante classification of the firm's EBA borrowing share. The $Post_{t-1}$ variable is a dummy variable equal to one if the observation is from the post treatment period in either group. We assume that the patent measures are affected with a 1-period lag by the treatment. This assumption is based on the consideration that it takes time for inventory outcomes to react to negative shocks in the availability of financial resources.[3] Further micro controls, $X_{ic,t-1}$, macro controls, $\omega_{c,t-1}$, and year controls, γ_{t-1}, are also added. Micro controls include the firms' logarithm of total assets, cash, equity, debt ratio, shareholder funds, net current assets, and intangible as well

[3]Further, the robustness tests include different lag specifications.

as other fixed assets. Industry fixed effects are based on the NACE Rev. 2 industry classification. Macro controls include measures on GDP per capita and GDP growth, balance of trade, labor productivity, R&D expenditures, a financial distress, and a financial crisis indicator for each of the countries. More details on the variables are in the appendix (see Table A.1).

4 Data

We use data from numerous sources. Information on individual firms' patenting activities comes from the Patstat database which is provided by the European Patent Office. Information on firms' financial statements comes from the Amadeus database which is provided by Bureau van Dijk. Information on firm-bank loan contracts stem from the Dealscan database at the Wharton Research Data Services. In addition to these firm-specific data, sector- and country-specific control variables are included in the analysis. Data on country-specific macro controls is derived from OECD's statistical database, OECD.Stats. Further controls are obtained from the European Central Bank'Äs (ECB) Statistical Data Warehouse and the World Bank's DataBank. A list of all firm-level and macro-level control variables is provided in the appendix (see Table A.1). The data cover the time period from 2000 to 2014 therefore spanning a couple of years before and after the EBA exercise.This period includes the financial crisis preceding the capital exercise and excludes the most current years. This exclusion is to deal with truncation issues regarding patent measures. Our analysis is also based on the rationale that restrictions in the availability of financial resources have a lagged effect on firms' innovative activities.

4.1 Patent Data

This subsection presents the measures of the qualitative and quantitative dimensions of patented inventions.

Qualitative Patent Measures We use a set of different proxies for patent quality. The first qualitative patent measure which is used in this study is forward citations that are the number of citations a particular patent receives from subsequent patents after its creation. The number of forward citations mirrors the technological importance of a patent for subsequent technologies that indicates its economic value (cf. Hall et al. (2005), Harhoff et al. (2003)).

A further qualitative patent measure relates to the so-called family size of a patent. The family size of patents is measured by the number of patent offices at which a given invention is filed (see Squicciarini et al. (2013).) According to findings in the patent literature, a patent's value is positively associated with the geographical scope of its protection (see, e.g., Harhoff et al. (2003) and Lanjouw and Schankerman (2004))

The third measure is a qualitative dimension of patented inventions that refers to the time span between the filing date of the application and the date the patent is granted by the authorities, that is, the grant lag. The value of a patent and the length of the grant lag are inversely related to each other, and more controversial claims lead to slower grants (see Harhoff and Wagner (2009)). Furthermore, applicants try to speed up the grant procedure for their most valuable patents (cf. Squicciarini et al. (2013)).

The value of a firm is significantly affected by the technological breadth of patents owned by a firm, that is, the patent scope (see Lerner (1994)). This variable captures the technological breadth of a patent application by counting the distinct International Patent Classes (IPCs) included in an application. Given that inventions can comprise combinations of existing ideas, the wider the set of ideas, the more valuable the patent (cf. Guellec and van Pottelsberghe de la Potterie (2000), Dechezleprêtre et al. (2017)). As a final measure, we also consider the withdrawals of patent applications. The EPO establishes the procedure for a patent application. In this procedure, the EPO searches for information on the relevant prior work of the applicant and determines its qualification. After the publication of this search report, the applicant has six months in order to file a request for examination. If this request is not filed, the EPO deems the application as withdrawn. The literature on patents has shown that withdrawals can be a signal that indicates the patentee considers the continuation of the application process to not be promising in relation to the expected marketability (cf. Long and Wang (2019)). Hence, withdrawals signal low patent quality.

Quantitative Patent Measures The standard quantitative patent measure is number of patents which were applied for by a firm at different patent offices. Another measure which is considered to capture the quantitative dimension of firms' inventive activities is the claims of a patent which give a clear and concise definition on the scope of what the patent legally protects (cf. OECD

(2009), Squicciarini et al. (2013)). The list of claims depicts the content of the claimed field of exclusivity. Recent descriptive analyses indicate that changes in the associated structures of claim fees included in the patent applications have an effect on the number of patent claims included in the respective applications (see Krzyzanowski (2019)).

4.2 Data Merges

The patent data complement the firm financials from the Amadeus database and the data on individual firm-level loans from the Thomson Reuters LPC Dealscan Database. The Patstat and Amadeus databases do not share a common identifier. Therefore, a sophisticated matching algorithm is needed to link the data from both sources with sufficient confidence. Furthermore, the data provided by the Patstat database are almost raw and therefore, have not undergone any form of standardization. Thus, several issues might arise, such as incorrectly spelled names, unstandardized addresses, misspecification of countries, or in general, missing data (see Peruzzi et al. (2014)). In order to link firms in Patstat to those in the Amadeus database, we need to substantially clean the data. This first step overcomes the potential ambiguities in the data by transforming the available information contained in Patstat. In the next step, we add the information from the Dealscan database to the Patstat-Amadeus database. For this purpose, we use string distance algorithms to match the firms' names, addresses, and country information. Based on an estimated matching probability cutoff of 90%, we establish the final self-generated bank-firm-level innovation panel dataset. Firms from the financial sector are excluded as well as those that have no total assets reported in a given year. To avoid survivorship biases, firms can freely enter or respectively drop out of the dataset. However, we exclude firms that do not appear for at least three consecutive years in the dataset. Also, all financial variables are normalized by total assets, if not indicated otherwise. Notably, during the matching processes, only those matches with sufficient confidence are considered to be true matches were used in the empirical part of this study. This normalization condensed the firms included in the empirical analysis. The final sample comprises an unbalanced panel dataset of 200 firms that result in 1,942 observations.

4.3 Descriptives

Table 1 depicts the industry shares of the firms which are based on the revised NACE classification of economic activities in the European Community. The table shows that most of the firms are engaged in manufacturing and scientific activities.

Insert Table 1 about here

Based on our classification of treated or non-treated firms, the following descriptives provide insights on how the firms with above median loan shares at EBA banks relate to the firms with below median loan shares at EBA banks (see Table 2) . In a first step, we compare the characteristics of exposed firms to those of non-exposed firms.

Insert Table 2 about here

Table 2 shows that the ex-ante classification of firms exposed to EBA banks does not result in major structural differences from the other firms.[4] Therefore, the exposed firms are relatively similar to non-exposed firms in terms of their geographical domestication and their industries. This finding is valuable for the below empirical difference-in-difference regression analysis. If there were substantial differences between the ex ante classified treatment and control groups, it would be difficult to argue that differences in the effect of the EBA capital exercise could not potentially be confounded by structural differences in the treatment and control groups of firms.

Table 3 provides comparative descriptives on the outcomes of the patent measures for the exposed and non-exposed firms. These results indicate that the two sets of firms are characterized by overall quite similar outcomes regarding both their quantitative as well as their qualitative outcomes.

Insert Table 3 about here

[4]Notably, exposed firms appear to be bigger in terms of their total assets while mean comparisons of the other financial measures do not result in statistical differences in means.

5 Results

This section contains the results of the difference-in-difference regression model. The results for both of the qualitative and qualitative patent measures are jointly displayed in Table 4, and the table shows that they support the two hypotheses of this study. The conventional view that a negative shock to the availability of financial resources affects the budgetary dimensions of firms' innovation is supported by the patent measure that capture the number of applications and therefore, is in line with the first hypothesis of this study. Furthermore, the second hypothesis, according to which the negative shock in the availability of financial resources has a positive effect on the qualitative dimensions of firms' innovation, is supported by the empirical findings on the patents' forward citations, family sizes, and withdrawals as well as the durations of the grants. While the estimations for forward citations and family sizes show positive and statistically significant coefficients for the DiD variable, the coefficient is negative and statistically significant for withdrawals and the grant lags, as conjectured in hypothesis 2.

Insert Table 4 about here

5.1 Robustness Tests

In less sophisticated specifications, we use a variety of fixed effects (in untabulated regressions) that leave the signs and dimensions on the DiD estimators unchanged overall. Furthermore, we note that so far, we have assumed that firms' innovation is affected by a 1-period time lag following the EBA capital exercise. The rationale for this consideration is that it takes time for innovations, which are capital intensive and, therefore, dependent on the availability of financial resources, to react to negative shocks to the availability of resources. If this is indeed the case, we predict that the derived estimates on the treatment effect should fade away and become insignificant if we remove the lag structure from the difference-in-difference model. Therefore, the subsequent regressions use the same difference-in-difference model except that the patent measures are not lagged by one period as in the baseline model but rather are in the same period as the remaining variables. The estimation results for this model specification are provided in Table 5. The outcomes on the parameter of interest are again highlighted in the framed box and include the numerical values for the DiD estimator, which captures the treatment effect in the different specifications in the difference-in-difference model with non-lagged patent measures. In comparison to the estimation results from Table 4, the difference-in-difference parameter becomes insignificant in all of the patent measures. Therefore, these regression results provide support for the validity of our findings because we would not expect any effects in the same period against the background of reaction lags.

Insert Table 5 about here

The final regression set refers to an analysis which goes beyond the specification of varying lag structures regarding the examined patent measures in the difference-in-difference model. The purpose lies in testing the validity of the estimation results in the context of the chosen identification strategy. If the findings so far indeed relate to the effect of the EBA capital exercise, the timing of the treatment regarding the exposure classification is vitally important in order to obtain valid outcomes that do not depict spurious estimation results on the treatment effect. The identification strategy in this study relates to differences in firms' exposures in their ex ante loan shares with the EBA banks, which decreased their available borrowing resources during this capital exercise.

Based on this consideration, the following regressions contain the estimation results of a placebo test which rests on an alternative timing of the treatment and which pretends that the EBA capital exercise was not introduced in 2011 but rather in the year of the outbreak of the financial crisis in 2007. The financial crisis itself had arguably an overall negative effect on the availability of financial resources which however did not only affect banks that participated in the EBA capital exercise but rather the whole banking sector in Europe and across the world. Therefore, if the outbreak of the recent financial crisis was chosen as the treatment and the exposure classification was still based on the firms' ex ante loan shares with the EBA banks as of 2010, the treatment effects should become insignificant in the placebo specification. This is because the outbreak of the recent financial crisis is likely unrelated to an exposure classification that refers to firms' borrowing shares in 2010 and, therefore, to a scheme which uses firms' borrowing data three years after the outbreak of the recent financial crisis. In fact, the estimation results on the treatment effects from Table 6 are statistically insignificant with respect to all patent measures considered. Based on the placebo treatment, the exposed firms are, therefore, not affected differently than the non-exposed firms in terms of their inventory outcomes. Consequently, this result strengthens the idea that the treatment effect is truly related to the EBA capital exercise. In summary, this results thus provide further support to the previous analyses that we do indeed capture the true causal effect of the negative shock to the availability of financial resources following the EBA capital exercise on the numerous dimensions related to firms' innovation based on the ex ante differences of firms' loan shares with EBA banks.

Insert Table 6 about here

6 Conclusion

In this study, we analyze the effect of decreases in available financial resources on the quantitative and qualitative dimensions of firms' innovation in relation to their patenting activities. For this purpose, the European capital exercise, which required a subset of European banks to substantially increase their capital ratios, provided the basis for a quasi-natural experiment that used an difference-in-difference regression setup in an European context. The literature shows that EBA banks increased their capital positions mainly by a substantial reduction in outstanding syndicated customer loans. Based on these considerations, firms were classified as being exposed to these negative consequences of the EBA capital exercise depending on their ex ante loan shares with EBA banks. Building on this exposure classification, we investigated the effect of the negative shock to different dimensions of firms' innovations.

Building on a unique, self-generated dataset, the empirical results support the ď?less finance, less innovation view. Higher capital requirements resulted in banks lending less to firms that led to less firm-level innovation in terms of budgetary patent measures, such as the number of filed patent applications and the amount of claims included in the patent documents. The qualitative dimensions of the patents, such as forward citations, family sizes, withdrawals, and grant durations, on the other hand were affected positively and therefore support the ď?less finance, less but better innovation view. This finding has in our view straightforward policy implications. Providing a framework which facilitates access to financing does not necessarily lead to better innovation and more productivity growth. Rather our findings call for a more subtle view on matters and more research on the overall net effect.

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Tables and Figures

Figure 1: Firm Debt Exposure Coefficient over Time

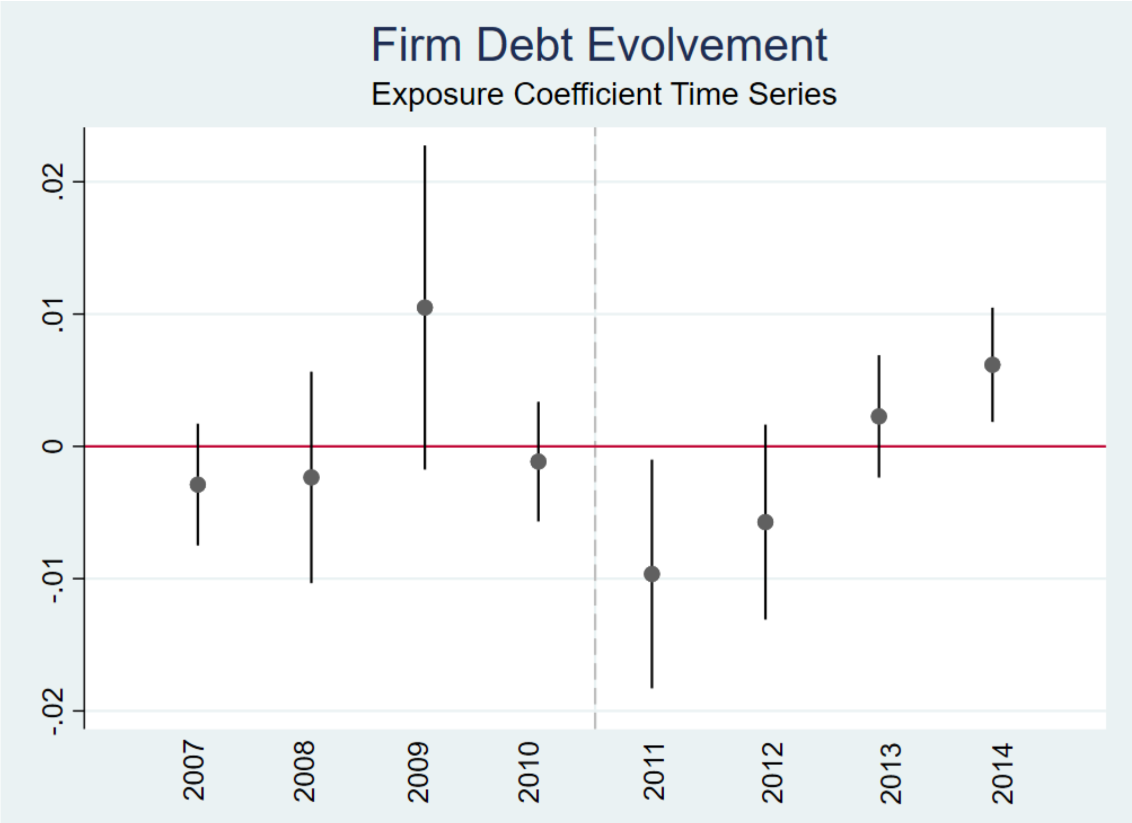

Table 1: Sample Firms NACE Industry Shares

Firm Industry Shares [Sample Firms – by NACE Classification]	
Agriculture & Mining	0.02
Info & Communication	0.07
Manufacturing	0.60
Retail Trade	0.06
Scientific Activities	0.16
Transportation	0.03
Other	0.06
N	1942

Table 2: Firm characteristics

Descriptive Statistics – Exposed Firms vs. Non-Exposed Firms						
		Total Assets (mn)	Debt Ratio	Equity Ratio	EBITDA/Assets Ratio	Cash Ratio
Exposed Firms	Mean	318	0.60	0.39	0.12	0.07
	p25	82	0.50	0.28	0.06	0.01
	Median	241	0.60	0.40	0.11	0.05
	p75	467	0.72	0.50	0.16	0.10
	Std. Dev.	282	0.20	0.19	0.08	0.09
Non-Exposed Firms	Mean	284	0.61	0.40	0.12	0.06
	p25	55	0.46	0.30	0.06	0.01
	Median	207	0.61	0.39	0.12	0.04
	p75	444	0.70	0.54	0.15	0.07
	Std. Dev.	265	0.20	0.19	0.08	0.08
Diff.		34	-0.003	-0.004	0.004	0.01
P-Value	*(diff = 0)*	*0.01*	*0.58*	*0.39*	*0.14*	*0*

Table 3: Descriptive Statistics of Patent Measures

Descriptive Statistics – Patent Measures (Exposed vs. Non-Exposed Firms)							
		Patent Applications	Patent Claims	Forward Citations	Family Size	Withdrawal Share	Grant Lag
Exp. Firms	Mean	28.54	3.78	3.90	5.47	0.17	3.19
	p25	3.00	1.66	1.75	2.83	0.03	1.99
	Median	10.00	2.66	3.00	4.50	0.07	3.10
	p75	37.00	4.67	4.68	7.00	0.22	4.18
	Std. Dev.	40.78	3.64	4.13	3.84	0.25	1.69
Non-Exp. Firms	Mean	28.59	3.67	4.28	5.87	0.18	3.53
	p25	3.00	1.63	2.00	3.00	0.04	2.41
	Median	10.00	2.44	3.50	4.68	0.11	3.42
	p75	38.00	4.34	5.42	7.33	0.25	4.33
	Std. Dev.	40.44	3.58	3.80	4.62	0.24	1.76
Diff.		-0.05	0.11	-0.38	-0.40	-0.01	-0.35
P-Value	*(diff = 0)*	*0.97*	*0.49*	*0.01*	*0.01*	*0.71*	*0.00*

Table 4: Difference-in-Difference Estimations – Main set-up

	Patent Applications	Patent Claims	Forward Citations	Patent Family Size	Patent Withdrawals	Patent Grant Lag
Treatment	0.021	-0.045	-0.003	0.072	-0.150	0.311
	(1.15)	(0.88)	(0.07)	(2.26)**	(1.48)	(2.57)**
Exposure	0.008	0.009	-0.004	0.003	0.009	0.001
	(0.96)	(0.60)	(0.45)	(0.27)	(0.81)	(0.05)
DiD-Estimator	-0.014	-0.007	0.031	0.020	-0.052	-0.052
	(2.15)**	(0.26)	(1.72)*	(1.83)*	(2.11)**	(1.79)*
Constant	0.016	0.462	-0.021	0.035	1.091	0.706
	(0.34)	(1.48)	(0.29)	(0.60)	(8.47)***	(3.91)***
Micro Controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Macro Controls	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adjusted R^2	.37	.25	.40	.25	.30	.27
N	1857	1841	1450	1857	1835	1609

This table presents the firm-level regression results for the most sophisticated difference-in-difference model including micro controls, macro controls, industry fixed effects, country fixed effects and year fixed effects for both, the budgetary and the qualitative patent measures. The sample consists of all firms in the intersection of Patstat, DealScan and Amadeus which are located in Austria, Belgium, Finland, France, Germany, the Netherlands, Sweden and the United Kingdom. The treatment is based on the execution of the European Capital Exercise vis-á-vis EBA banks, whereas the firms' exposure to the treatment is based on the ex-ante median split of their lending shares towards these banks. Micro controls include firms? logarithm of total assets, cash, equity, debt ratio, shareholder funds, net current assets, intangible as well as other fixed assets. Industry Fixed effects are based on the NACE Rev. 2 industry classification. Macro controls include measures on GDP per capita and GDP growth, balance of trade, labor productivity, R&D expenditures, a Financial Distress Indicator and a Financial Crisis Indicator for each of the countries. Details on the variables are depicted in subsection 8.1. Standard errors are adjusted for heteroscedasticity and clustered at firm level. Significance levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Table 5: Difference-in-Difference Estimations – Simultaneous effects

	Patent Applications	Patent Claims	Forward Citations	Patent Family Size	Patent Withdrawals	Patent Grant Lag
Treatment	0.021	-0.036	0.002	0.039	-0.031	0.238
	(1.45)	(0.71)	(0.05)	(1.58)	(0.62)	(2.54)**
Exposure	0.006	0.009	0.001	0.004	0.005	0.003
	(0.79)	(0.65)	(0.12)	(0.34)	(0.49)	(0.19)
DiD-Estimator	-0.010	0.019	0.016	0.008	-0.010	-0.049
	(1.62)	(0.74)	(1.39)	(0.66)	(0.38)	(0.80)
Constant	0.194	0.440	-0.062	-0.054	0.730	0.908
	(1.62)	(1.52)	(0.82)	(0.34)	(2.28)**	(6.29)***
Micro Controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Macro Controls	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adjusted R^2	.32	.25	.46	.25	.40	.30
N	2001	1990	1698	2001	1985	1840

This table presents the robustness test firm-level regression results for the most sophisticated difference-in-difference model including micro controls, macro controls, industry fixed effects, country fixed effects and year fixed effects for the non-lagged budgetary and the qualitative patent measures. The sample consists of all firms in the intersection of Patstat, DealScan and Amadeus which are located in Austria, Belgium, Finland, France, Germany, the Netherlands, Sweden and the United Kingdom. The treatment is based on the execution of the European Capital Exercise vis-á-vis EBA banks, whereas the firms' exposure to the treatment is based on the ex-ante median split of their lending shares towards these banks. Micro controls include firms? logarithm of total assets, cash, equity, debt ratio, shareholder funds, net current assets, intangible as well as other fixed assets. Industry Fixed effects are based on the NACE Rev. 2 industry classification. Macro controls include measures on GDP per capita and GDP growth, balance of trade, labor productivity, R&D expenditures, a Financial Distress and a Financial Crisis Indicator for each of the countries. Details on the variables are depicted in subsection 8.1. Standard errors are adjusted for heteroscedasticity and clustered at firm level. Significance levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Table 6: Placebo estimates

	Patent Applications	Patent Claims	Forward Citations	Patent Family Size	Patent Withdrawals	Patent Grant Lag
Treatment (Crisis)	0.003	-0.064	-0.032	0.132	-0.065	0.126
	(0.18)	(1.10)	(0.61)	(4.03)***	(1.02)	(1.39)
Exposure	0.011	0.003	-0.008	0.006	0.011	-0.000
	(1.35)	(0.15)	(0.98)	(0.42)	(0.60)	(0.01)
DiD (Placebo)	-0.009	0.008	0.014	-0.000	-0.015	-0.009
	(0.95)	(0.37)	(1.36)	(0.05)	(0.63)	(0.38)
Constant	0.010	0.555	-0.016	0.037	1.073	0.739
	(0.21)	(1.99)**	(0.21)	(0.64)	(8.03)***	(4.15)***
Micro Controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Macro Controls	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adjusted R^2	.37	.25	.40	.25	.30	.27
N	1857	1841	1450	1857	1835	1609

This table presents the placebo test firm-level regression results for the most sophisticated difference-in-difference model including micro controls, macro controls, industry fixed effects, country fixed effects and year fixed effects for budgetary and the qualitative patent measures. The sample consists of all firms in the intersection of Patstat, DealScan and Amadeus which are located in Austria, Belgium, Finland, France, Germany, the Netherlands, Sweden and the United Kingdom. The treatment is based on the execution of the European Capital Exercise vis-á-vis EBA banks, whereas the firms' exposure to the treatment is based on the ex-ante median split of their lending shares towards these banks. Micro controls include firms? logarithm of total assets, cash, equity, debt ratio, shareholder funds, net current assets, intangible as well as other fixed assets. Industry Fixed effects are based on the NACE Rev. 2 industry classification. Macro controls include measures on GDP per capita and GDP growth, balance of trade, labor productivity, R&D expenditures, a Financial Distress and a Financial Crisis Indicator for each of the countries. Details on the variables are depicted in subsection 8.1. Standard errors are adjusted for heteroscedasticity and clustered at firm level. Significance levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Appendix

Table A.1: List of Firm-Level and Macro-Level Control Variables

Patent Measures

Variable	*Definition*
Patent Claims	$claims_p = n_p^{claims}: n \in \{claim_1, \ldots claim_{i,} \; claim_j, \ldots, claim_n\} \; \& \; claim_i \neq claim_j$
Forward Citations	$forward\ citations_p = \sum_{t=T}^{T+5} \sum_{j \in Q(t)} C_{p,q}$
Family Size	$family\ size_p = n_p^{jur}: n \in \{jur_1, \ldots jur_{a,} \; jur_b, \ldots, jur_J\} \; \& \; jur_a \neq jur_b$
Patent Withdrawal	$withdrawal_p = I_p \in 0{,}1$; 1 if patent p withdrawn by patentee; 0 else.
Grant Lag	$grant\ lag_p = \Delta t(application\ filing\ date_p \; ; grant\ date_p)$

Firm-Level Financials

Variable	*Definition*
ln(Assets)	Natural logarithm of total assets
Cash Ratio	$\frac{Cash}{Total\ Assets}$
Debt Ratio	$\frac{Current+Non\text{-}Current\ Liabilities}{Total\ Assets}$
EBITDA/ Assets	$\frac{EBITDA}{Total\ Assets}$
Equity Ratio	$\frac{Equity}{Total\ Assets}$

Macro-Level Variables

Variable	*Definition*
Balance of Trade	Exports – Imports of goods and services
CLIFS	Country-Level Index of Financial Distress (ECB)
Crisis	Indicator variable equal to one for the period of a banking crisis based on Laeven & Valencia (2013)
GDP per Capita	$\frac{Total\ GDP}{Total\ Population}$
GDP per Capita Growth	$\frac{GDP\ per\ capita_t - GDP\ per\ capita_{t-1}}{GDP\ per\ capita_{t-1}}$
Labor Productivity	$\frac{GDP}{hours\ worked}$

Table A1 contains the definitions on the generated variables which were utilized in the empirical part of this paper, either in the descriptive analyses or in the regression analyses. Regarding the patent measures, the definitions are provided on individual patent level basis, *p*. The forward citations measure refers to a patent filed in year t=T, while Q(t) refers to the set of all patent applications q filed in year t and $C_{p,q}$ refers to a dummy variable which equals 1 if patent q cites patent p and equals zero otherwise. Regarding the family size measure, the *jur* indicator relates to distinct patent office jurisdictions in which a particular patent seeks for protection. While many of the measures are time invariant by construction, corresponding firm-level patent measures may vary over time as firms file numerous patents over time with diverse individual patent measure outcomes. Based on these considerations, time-variant patent measures on firm-level basis can be generated and utilized in the firm-level regression analyses. The patent measures are generated as normalized variables by means of dividing the initial results by the maximum score obtained in the same year and technology field cohort over a 98% winsorized distribution in order to deal with technological fluctuations, spurious outliers as well as to adjust for potential institutional changes, for instance in patent office policies. Details on patent measure specific evolvements over time, industry and firm countries, as well as discussions on associated structural issues in context of patents filed by European firms can be found in Krzyzanowski (2019). In order to reduce the potential for distortion which may be caused by spurious outliers, the variables depicted below are constructed over a 98% winsorized distribution, i.e. indicators below the 1st percentile are transformed into values corresponding to the 1st percentile and those indicators above the 99th percentile are set to the 99th percentile.

Table A.2: List of Banks included in EBA Capital Exercise

Bank	**Country**
Erste Group Bank AG	Austria
Raiffeisen Zentralbank Österreich AG	Austria
KBC Bank	Belgium
Bank of Cyprus Public Co. Ltd.	Cyprus
Cyprus Popular Bank Public Co. Ltd.	Cyprus
Danske Bank	Denmark
Jyske Bank	Denmark
Nykredit	Denmark
Sydbank	Denmark
OP-Pohjola Group	Finland
BNP Paribas	France
BPCE	France
Credit Agricole	France
Societe Generale	France
Bayerische Landesbank	Germany
Commerzbank AG	Germany
DekaBank Deutsche Girozentrale	Germany
Deutsche Bank AG	Germany
DZ Bank AG DT.-Zentral-Genossenschaftsbank	Germany
HSH Nordbank AG	Germany
Hypo Real Estate Holding AG	Germany
Landesbank Baden-Württemberg	Germany
Landesbank Berlin AG	Germany
Landesbank Hessen-Thüringen Girozentrale	Germany
Norddeutsche Landesbank Girozentrale	Germany
Westdeutsche Genossenschafts-Zentralbank AG	Germany
OTP Bank Nyrt.	Hungary
Allied Irish Banks, Plc	Ireland
Bank of Ireland	Ireland
Irish Life and Permanent	Ireland
Banca Monte dei Paschi di Siena S.p.A.	Italy
Banco Populare – S.C.	Italy
Intesa Sanpaolo S.p.A.	Italy
Unicredit S.p.A.	Italy
Unione di Banche Italiane SCPA	Italy
Banque et Caisse d'Epargne de l'Etat	Luxembourg
Bank of Valletta (BOV)	Malta
ABN AMRO Bank NV	Netherlands
ING Bank NV	Netherlands
Rabobank Nederland	Netherlands
SNS Bank NV	Netherlands

DNB NOR Bank ASA	Norway
Powszechna Kasa Oszczednosci Bank Polski S.A.	Poland
Banco BPI SA	Portugal
Banco Comercial Português S.A.	Portugal
Caixa Geral de Depositos S.A.	Portugal
Espirito Santo Financial Group S.A.	Portugal
Nova Kreditna Banka Maribor d.d.	Slovenia
Nova Ljubljanska Banka d.d.	Slovenia
Banco Bilbao Vizcaya Argentaria S.A.	Spain
Banco Popular Español S.A.	Spain
Banco Santander S.A.	Spain
Caja de Ahorros y Pensiones de Barcelona	Spain
Nordea Bank AB	Sweden
Skandinaviska Enskilda Banken AB	Sweden
Svenska Handelsbanken AB	Sweden
Swedbank AB	Sweden
Barclays plc	United Kingdom
HSBC Holding plc	United Kingdom
Lloyds Banking Group plc	United Kingdom
Royal Bank of Scotland Group plc	United Kingdom

Table A2 contains the list of all banks which were included in the EBA capital exercise in 2011. For more details see *https://eba.europa.eu/risk-analysis-and-data/eu-capital-exercise/final-results.*