No Pressure, No Diamonds? Financing Constraints and their Quantity-Quality Effects on Inventions*

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This paper explores the effect of policy-induced reductions in financing constraints on the quantity and quality of firm-level inventions, namely patents. To study this, I utilize exogenous variation in access to funding arising from the staggered adoption of a major EU policy initiative harmonizing financial markets across member states. Relaxing financing constraints boosts firms' patent filings but also leads to a modest decline in patent quality along several dimensions, suggesting negative marginal returns. However, effects on patent quality are reversed for firms with low initial patenting activities, which highlights the relevance of proper funding to spur commercialization of early-stage inventions.

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1 Introduction

Financial resources are essential to enable the initial development and diffusion of firm-level inventions (e.g., Kerr and Nanda 2015, Nanda and Rhodes-Kropf 2016). Relaxing constraints in the access to financial resources is associated with higher R&D expenditures (Brown *et al.* 2009), long-term research investments (Aghion *et al.* 2010), and patent filings (Chava *et al.* 2013). While these features suggest harmful effects of constraints on the quantity of firm-level inventive activities, several studies indicate that constraints can be beneficial for the quality of inventions. For example, research shows that constraints can act as a disciplining device inducing innovative efficiency on an individual (Ederer and Manso 2013), governmental (Gibbert and Scranton 2009), or firm level (Almeida *et al.* 2017).[1] Yet, the potential positive effects of financing constraints

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[1] Complementary empirical evidence highlights the presence of heterogeneous effects regarding the effects of financing constraints on inventive activities by considering the effect of changes in the direct costs of patenting. Historical changes in filing fees are associated with a strong negative effect of higher costs on the number of patent applications (e.g. Eaton *et al.* 2004), whereas de Rassenfosse and Jaffe (2018) find that increased filing costs predominantly crowd out low quality applications and thus enhance average patent quality. A recent policy

have to be limited by definition, as fewer and fewer resources cannot lead to ever more or better inventive output.

A priori, it is thus not clear whether relaxing constraints possibly causes heterogeneous or even undesirable effects on inventive activities. Providing empirical evidence on this issue is highly relevant, since mitigating financing constraints is a favorable target by policymakers and businesses in the attempt to spur inventive activities (Howell 2017). Hence, better understanding potential mechanisms and consequences of policy-induced reductions in financing constraints is important for effective decision-making on a governmental and business level. In this context, it is crucial to take the quantity and quality of inventive outcomes into account because both are simultaneously relevant for the economic success of firms. While the magnitude of the inventive output is a necessity for economic progress, e.g., due to its potential to release externalities, quality features are associated to affect pervasiveness and the potential to create value in the long-run (Harhoff and Wagner 2009).

Against this background, the question arises whether and how relaxing financing constraints affects firm-level inventive output. In particular, is there a differential effect of improved access to funding on the quantity and quality of firms' inventive activities? To the best of my knowledge, this analysis provides the first large scale, firm-level evidence on these questions. Using highly granular patent information to measure firms' inventive activities allows to precisely capture its quantity dimension and discloses a variety of quality features. I leverage several measures on patents' technological quality and market value as well as the degree of exploration to capture a broad view on patent quality attributes. For enabling causal inferences, I exploit plausibly exogenous variation in financing constraints induced by major changes in the European Union's legislative framework during the 2000s.

The main results retrieved through generalized difference-in-differences estimations suggest positive effects on quantity dimensions. Moving the average treated firm from pre- to post-financial market integration causes a 44% increase in patent filings (i.e. 3 patents per year) relative to the control group. With regard to patent quality, two key findings which consistently apply for a variety of patent quality dimensions best summarize the main effects. First, I do not find any evidence for a potential positive effect of integration on patent quality for the average firm. Second, effects are persistently negative across a variety of quality measures. However, results mostly lack statistical significance and are not economically meaningful in terms of size. These two insights allow rejecting the hypothesis of a positive effect of an exogenous improvement in firms' access to funding on patent quality. Yet, claiming a trade-off between patent quantity and quality cannot be made without restriction, since negative effects for the average firm are only partially supported by the data. I further show that financial market integration has an effect

example is the announcement of the British Patent Office (UKIPO) in 2018 to substantially adjust their patenting fees structure. With the specific aim of "*encourag[ing] good filing practices by applicants*" (UKIPO 2018), UKIPO increased filing fees (by 300%), filing surcharges (25%), examination fees (25%), and basic search (15%).

on the type of patents filed by contrasting explorative and incremental patenting types. Firms shift towards filing patents that protect rather incremental inventions, which are characterized by a relatively low impact on subsequent technology and narrower technological scope. Again, results are rather weak compared to the baseline results on patent quantities.

As an important addition, I analyze whether additional funding induces firms to change the focus of their investments, i.e., the general direction of their research strategies. Specifically, results illustrate that the increased use of debt allows higher expenditures on patenting in absolute terms. Yet, on average, the increase in expenditures is proportional to the increase in debt. These results provides two main insights. First, they support the empirical strategy by suggesting that firms use additional debt to invest in patenting. Second, they suggest that firms do not change the focus of their investments in response to increased funding.

I explore heterogeneous treatment effects which helps to better understand several potential mechanisms behind the main findings. Intuitively , the baseline effects should vary by firms' sensitivity to the treatment. Distinguishing among high and low pre-treatment patenting intensities shows that firms similarly increase patent quantities as a response to the treatment, but the negative effects on patent quality are particularly pronounced for firms with high pre-treatment patenting intensities. For these firms, the likelihood of having already realized their most promising projects is high and, thus, enlarging their patenting activities comes at the cost of adding patents of relatively lower quality to their portfolio. Here, decreasing returns to investment in inventive activities (Lokshin *et al.* 2008) is likely a mechanism which accounts for the opposing effects regarding the quantity and quality dimensions. In contrast, for firms with low ex-ante patenting intensity, effects are reversed and relaxing financing constraints has a positive effect on the quality of their patented inventions. This suggests that small and young firms benefit from additional funding both in terms of patent quantity and quality which is consistent with the idea that financial resources are a key input for initiating commercialization and diffusion of inventive output (Nanda and Rhodes-Kropf 2016).

A central threat to the validity of these results are reverse causality and endogeneity concerns. It is plausible to assume that financing constraints influence inventive activities but, at the same time, firms' inventive output also affects the availability of financial resources (e.g. Mann 2018, Hochberg *et al.* 2018). Moreover, there might be unobserved simultaneous factors which jointly drive patenting behavior, such as general invention trends and macroeconomic conditions. I therefore address these concerns in multiple ways. Most importantly, my analysis builds on a quasi-experimental setup that helps to establish the causal relationship between financing constraints and patenting.

More specifically, I exploit the Financial Services Action Plan (FSAP) in the European Union (EU) as an identifying event. The market reform entails the staggered implementation of legal amendments across member states as an effort by the European Commission to enhance financial integration within the EU during the 2000s. In particular, I draw on seven bank-related FSAP amendments as a traceable, exogenous source of variation in firms' legal environment improving borrowing conditions across countries (Kalemli-Özcan *et al.* 2013). Thus, the bank lending channel constitutes the link between changes in financing conditions and inventive outcomes. This appears to be particularly suitable, since more than 95% of sample firms are privately-held, small and medium-sized firms which depend more strongly on banks as providers of external funding compared to large public firms (Berger and Udell 2006).

For identification, I utilize both cross- and within-country heterogeneity in the data. Variation on the country level arises from the time differences of the FSAP implementation dates across member states. Further, I estimate firms propensity to be ex-ante financially constrained to distinguish between affected and unaffected firms within countries. Hence, the identifying assumption is that financial market integration has a disproportionate effect on access to funding fro ex-ante constrained firms. To verify this, I show that the FSAP amendments reduce interest burdens for affected firms and thereby enhances their debt capacity. Comparing pre- and post-integration levels for ex-ante constrained firm shows that the average decrease of interest charges is about 15% higher and the average increase in the use of bank loans is about 10% higher relative to unconstrained firms.

Furthermore, additional analyses test alternative hypotheses and investigate the plausibility of the main results. First, a series of analyses on pre-trends and lagged effects supports the empirical strategy and further suggest that (*de jure*) changes in the legal framework require some time to have quantifiable (*de facto*) effects. This supports the assumption that the timing of financial integration is exogenous to patenting activities. Second, I test whether alternative events better explain my main results by using the introduction of the Euro in 1999 as a placebo setting. This event has several favorable features: economic fluctuations are comparable to those in the original setting; it marks a major event of financial market integration; at the same time, it should plausibly not change financing conditions for the category of firms considered as treated in the original setting. Results show that the placebo event fails to explain changes in patenting and financing activities. This is consistent with the idea that the baseline effects arise from changes in borrowing conditions and not general macroeconomic conditions or existing time trends. Third, I repeat the main analysis but differentiate between private and public firms. The implicit assumption is that publicly traded firms are found to have better access to alternative external funding sources (La Porta *et al.* 1997) and therefore should be less responsive to changes in access to external funding. Separately running the analyses for the two types of firms confirms this assumption: baseline effects are large and statistically significant for private firms, whereas estimates for the subset of public firms are small and statistically insignificant. This finding is consistent with evidence suggesting that smaller firms react to financial cycles with larger adjustments in research spendings as compared to large corporations (Brown *et al.* 2009). It further implies that positive shifts in the access to external debt due to the FSAP implementation disproportionally relaxed financing constraints for ex-ante constrained firms – an observation which is in line with the identification assumption. Although omitted variable concerns can never be entirely ruled out, these analyses mitigate doubts about the causal interpretation of the results.

This study extends existing literature in multiple ways and relates primarily to three main areas of research that focus on the determinants of inventive activities (in order of priority): i) the availability of financial resources, ii) incentives to innovate, and iii) economic development.[2] More specifically, I provide novel insights how financial constraints shape inventive activities along multiple patenting dimensions by analyzing a broad set of value-relevant characteristics of inventions. These features highlight the importance of appropriate funding for spurring inventive activities. At the same time, I am able to draw a more comprehensive picture regarding multi-dimensional effects of relaxing financing constraints on firm-level inventions. Examining a large number of predominantly small and medium-sized, privately-held firms allows to trace potential mechanisms behind the main results and thus provides new evidence on the tight link between financial constraints and firm-level inventive activities. Finally, my findings are generally consistent with the literature on economic development by illustrating beneficial effects of market integration. In addition to this, the divergent results deliver important insights regarding potential limitations of investment policies focusing on monetary input to support innovation. They raise questions about policy efficiency, while stressing the importance to acknowledge the diversity of inventive outcomes, particularly with regard to quality features.

The paper proceeds as follows. Section 2 describes the data and patenting dimensions. Section 3 outlines the institutional background of the identifying event and my empirical strategy. Section 4 presents the main results and several extensions to enable better inferences on the empirical mechanisms. Section 5 concludes.

2 Data and Measurement

2.1 Data set and coverage

The data base mainly consists of firm-level financial information from several historical copies of the Amadeus database combined with patent information from the PATSTAT database, which encompasses the universe of European patenting activities on a highly granular level. These information are augmented with manually collected country-specific information on FSAP implementation dates as well as additional macro-level control variables.

I sample firms for the years 2000 to 2008 capturing a broad time frame around the implementation phase of the FSAP amendments.[3] By selecting this time frame I keep a symmetric time

[2] For a comprehensive overview on the literature and its relation to this study, see Appendix A.

[3] For the placebo analysis in Section 4.4.1, data is added on the four preceding years (i.e. 1996-1999).

window around the main phase of financial integration and avoid potential confounding factors relevant to the financing behavior of firms, such as the Financial Crisis (2009). Table 1 displays the ten sample countries, all of which are EU member states at the time of the FSAP drafting.[4] Firms are allowed to enter and leave the database in order to avoid potential survivorship bias. On average each firm is observed 6.8 times. Observations with zero or negative total assets, firms that cannot be categorized in industry-classes, and firms from the financial or public sectors are excluded. Accounting for outliers, variables are windsorized at the 1 percent level. The final sample consists of 125,300 observations (24,736 firms) from 10 different countries, 15 industries and incorporates information on 662,995 patent applications.

- Insert Table 1 here -

2.2 Measuring inventions and descriptive statistics

Reliable measurement of inventions is a key challenge for studying the effects of financial constraints on inventive activities. The intangible nature of inventions poses a threat to precise quantification of firms' inventive activities. I use patent information to mitigate this issue. Arguably, patents have a certain degree of asset tangibility, since they are well-documented, legally protected property rights. As an important additional feature, the thorough documentation of patenting reveals various facets of the underlying technology and allows to reliably identify different patenting characteristics.

The most common approach for investigating patenting is the assessment of quantity dimensions. The number of patent applications reflects the actual level of inventive output.[5] As an important complement, patent quality can be defined as the size of the inventive step that is protected by a patent (de Rassenfosse and Jaffe 2018). The respective size of this step plausibly makes it more difficult to invent around a patent and lengthens the monopoly period for the patent holder. Indeed, enhancing invention quality increases firms' probability of survival (Hall and Harhoff 2012), whereas a lack of quality is harmful for firm-level growth and employment (Hall *et al.* 2004).

I consider the number of citations received as well as the number of claims included in patent applications as dimensions describing the technological quality of a patent. Higher quality patents are expected to receive a larger number of citations, because a larger number of citations reflects the impact of a patent on subsequent inventions (de Rassenfosse and Jaffe 2017). In addition, the number of claims included in a patent application indicates the legally protected properties of an invention. This relates to the extent of market power attributed to the patented

[4] Initially, all EU15 countries are regarded as potential sample countries, because the FSAP Directives was targeted at the EU member states of the late 1990s. Due to bad coverage during the early 2000s in the historical Amadeus copies, Austria, Greece, Luxembourg, Portugal, and Spain are excluded.

[5] The four requirements for the patentability according to the European Patent Convention (EPC 1973, Art. 52(1)) specifically do not address quality aspects but: i) a "*technical character*", ii) "*novelty*", iii) a non-obvious "*inventive step*", and iv) susceptibility to "*industrial application*".

invention and is thus positively associated with quality (OECD 2009). Claims are normalized by backward citations (i.e. references included in a patent description) to control for patents' legal boundaries with respect to the prior art. These two measures are not only relevant in terms of technological quality but are also positively related to the ex-post value of a patent (de Rassenfosse and Jaffe 2018).

To assess market value separately, I consider two additional measures which directly relate to the market value but are independent from patents' technological features, i.e. the number of patent offices a patent is filed at and the number of annual patent renewals payments. These two aspects directly affect patenting costs, which are particularly high and thus economically relevant in Europe (de la Potterie 2010). Literature associates more valuable patents with a larger international scope (Harhoff *et al.* 2003) and a longer lifespan, i.e. more renewals (Schankerman and Pakes 1986).[6] This is in line with the notion that firms' willingness to repeatedly incur these costs indicates the underlying patent value.

To incorporate more general patent categories, my analysis further distinguishes between explorative and incremental patents, which differ according to their degree of novelty and impact on subsequent inventions. Explorative patents are characterized by riskier, large steps but also higher impact, whereas incremental patents involve rather marginal improvements with no significant impact on follow up inventions. Both types are generally value-relevant from a firm-perspective. Explorative inventions have groundbreaking potential, possibly delivering high returns, whereas the successive but steady improvements of incremental inventions potentially deepen revenue generating capacities of existing inventions (Henderson 1993).

Appendix B presents more details on the patenting dimensions, their construction, and mutual relations. All patent quality measures (summarized in Table 2) refer to individual patent-level information but are aggregated on a firm-year level to match the panel structure of the financial information. Summary statistics show that patenting activities are heterogeneous both across and within countries. Large countries (i.e. Germany, France, and Great Britain) are dominant with regard to the number of patents filed (see Table 1 in the previous section). Similarly, there patenting activities form major clusters on specific sectors. For example, the majority of patents (64.7%) are filed by firms in the manufacturing sector (see Table A1 in Appendix E). These observations reflect structural differences in patenting activities. However, it does not imply that certain sectors or countries are more or less innovative. Instead, it indicates differences in their propensity to patent.

- Insert Table 2 here -

Table 3 displays summary statistics on key financial (Panel A) and patenting variables (Pan-

[6] I do not use market-value-based patenting measures, such as those introduced by Kogan *et al.* (2017), because the vast majority of sample firms is privately owned (i.e. without stock price data). It is possible to approximate market values by matching on observable patent characteristics. However, the strong discrepancy between the reference group and sample firms questions such an approach.

els B and C). With a mean age of 25.7 years, firms are generally well established. More notably, only 4.7% of sample firms are listed corporations which is consistent with the true European business landscape that includes mostly small and medium-sized private firms. Moreover, descriptives show that patenting activities vary significantly on the firm level. Heterogeneity is high both in terms of patent quantity and quality, which is in line with previous observations (e.g. Gambardella *et al.* 2007). While some companies file no patents in a given year, others apply for almost 3,000 patents. At the same time, the distribution of patents is notably skewed towards low impact patents. Incremental patents make up a large fraction among all patents (43.5%), but only a comparably small fraction of patents appears to have a high impact on subsequent inventions (6.1%) or can be considered as explorative (2.0%).[7] Descriptive statistics overall indicate that the sample comprises a representative set of patenting firms and industries in Europe.

- Insert Table 3 here -

3 Institutional Background and Empirical Strategy

Studying the relationship between financial constraints and inventive activities entails obvious endogeneity issues. The empirical analysis therefore uses European financial market integration throughout the 2000s as exogenous source of variation in firms' access to funding. Particularly, I assess the effect of specific banking-related changes in EU law as stipulated by the so-called Financial Services Action Plan (FSAP). In the following, I provide institutional information on the FSAP, the measurement approach, and identification strategy.

3.1 Financial integration in Europe: The FSAP

The FSAP was officially issued by the European Commission in 1999. The prime strategic intention was to integrate financial markets within the European Union by further harmonizing its regulatory framework. The Commission developed the reform along four objectives: a single EU wholesale market, open and secure retail banking and insurance markets, state-of-the-art prudential rules and supervision as well as advancing towards an optimal single financial market. It assigned EU member states to implement 42 legislative amendments over a time span of six years. These amendments included 29 major pieces of legislation (27 EU Directives and two EU Regulations) in the fields of banking, capital markets, corporate law, payment systems, and corporate governance. Out of this, my analysis considers all banking-related directives.[8]

[7] Resulting from the applied classification scheme, 54.5% of patents are neither incremental nor explorative and can be considered as benchmark group. This approach has the advantage that incremental and explorative patents can be independently observed and thus analyzed. In contrast, a binary classification would have the mechanical constraint that all patents which are not incremental would be – qua definition – explorative, and vice versa. Table A2 (Appendix E) reports the correlation matrix of the main patent variables. Inevitably, some measures are correlated, since the patent type variables build on certain patent quality and value characteristics.

[8] Table A3 in Appendix E lists all FSAP Directives. Appendix C provides more information on EU Directives and an elaborate discussion about endogeneity concerns.

Importantly, the legislative changes had strong effects on European financial market integration. Empirical evidence confirms a notable fragmentation of European markets before the FSAP introduction during the late 1990s (e.g. Adam *et al.* 2002), whereas market harmonization strongly increased during the 2000s as a consequence of changes in law as stipulated by the FSAP. Kalemli-Özcan *et al.* (2013) show that business cycle synchronization was strongly enhanced as a direct effect of the FSAP. In a more general manner, Meier (2019) and Malcolm *et al.* (2009) stress the importance of the amendments for providing confidence in the reliability of financial regulation itself. Likewise, Quaglia (2010) argues that the FSAP represented a change in EU strategy away from market opening measures and towards common regulatory measures. To provide one distinct example, the so-called Capital Requirements Directives as one part of the FSAP allowed banks to reduce their regulatory capital requirements for claims on SMEs for a given level of risk. The directives directly improved small firms' access to bank funding (Aubier 2007), which is of particular relevance in my setting.

Aggregate statistics support these findings. For example, Figure A1 (Appendix F) plots quantity- and price-based indicators of financial integration measuring loans to non-financial firms provided by monetary financial institutions. Both measures exhibit a sizable increase during the mid-2000s suggesting that the implementation process of FSAP Directives is positively associated with financial market integration in Europe.

Building on this evidence, the key identifying assumption is that harmonization facilitated access to bank finance. Presumably, this relaxes financing constraints of firms across EU member states. The underlying mechanism is that more integrated markets facilitate both cross-border and domestic lending activities. Hence, a more integrated market should lead to better borrowing conditions due to higher competition among banks (e.g. Chava *et al.* 2013) and lower informational asymmetries between lenders and potential borrowers (e.g. Liberti and Mian 2010). Ceteris paribus, this should induce firms to take on more external debt.[9] Exploring variation in borrowing conditions is promising, since debt finance plays a relatively important role for smaller, research intensive firms (Kerr and Nanda 2015) and should therefore be particularly relevant for sample firms. The timing and the intensity of the shift is heterogeneous across firms which allows estimating causal effects in a difference-in-differences setup.

3.2 Quantifying financial integration

To quantify financial integration, I use manually collected data on the actual country-specific transposition dates for the seven banking related FSAP Directives. The (*de jure*) integration measure captures the timing of implementation by:

[9] I test these propositions in Section 4.2. Appendix C introduces more details on the FSAP's effects.

$$FI_{ct} = \frac{1}{7} \sum_{d=1}^{7} \left(D_{dtc} \times \frac{\sum_{j \neq c} D_{dtj}}{14} \right) \tag{1}$$

where D_{dtc} and D_{dtj} ($\forall\ d \in [1, 7]$) are equal to one, if one of the seven banking-related FSAP Directives is active during the year t ($\forall\ t \in [2000, 2008]$) in country c, or country j (with $c \neq j$) respectively, and zero otherwise. To introduce the multilateral dependence, the indicator variable for the observed country c is multiplied by the fraction of all other EU-15 members j in which the respective directive is active. The financial integration measure thus ranges between zero and one. Figure 1 displays the evolution of the time-varying and country-specific FI_{ct} measure as defined in Equation (1) over time. Between the years 2000 and 2004, financial integration progresses relatively slow compared to the second phase between 2004 and 2008. The magnitude of the integration index reflects the mutual implementation of directives across countries.[10]

- Insert Figure 1 here -

The specific modeling of the measure mitigates endogeneity concerns for several reasons. First, EU Directives are considered non-anticipatory, as they become effective on an individual country-specific basis after passing domestic legislation (Kalemli-Özcan *et al.* 2010, 2013). The exact timing is unlikely to be anticipated, because implementing these directives usually varies considerably across member states and does not happen based on the predefined deadlines. Second, implementation is unlikely to reflect market responses several years later, since the original schedule of the FSAP was set in the late 1990s (Christensen *et al.* 2016). Third, the implementation of the directives is a domestic matter, whereas financial integration is a multilateral concept. The measurement approach from Equation (1) accounts for this by weighting the implementation of directives by mutual implementation of other EU members. Fourth, EU decisions are made on a supra-national level which makes it unlikely for (mostly small) individual firms' actions to be related to country-specific initiatives (Schnabel and Seckinger 2019). Finally, FSAP Directives do not specifically target patenting activities by any means.

3.3 Identification strategy

To assess the impact of relaxed financing constraints on patenting activities, I employ a generalized difference-in-differences (DID) approach (Angrist and Pischke 2008). The implementation of the seven relevant FSAP Directives constitutes a continuous treatment that affects firms across countries with different intensities and at different points in time. For identification, I further

[10] Considering a stylized, three-country scenario: if country A implements all FSAP Directives but country B and C do not implement any directives, no integration would be reached. If county A and B adopt all respective laws but C does not, FI_{ct} is equal to 0.5 for countries A and B, and 0 for country C. Only in the case that all countries implement all directives at a given point in time, the measure equals 1. Figure A2 (Appendix F) displays the fraction of implemented directives per country over time, resembling the integration measure without considering the aspect of multilateral adoption.

utilize heterogeneity among sample firms regarding their propensity to be affected by the legislative amendments. Improved access to funding is unlikely to have a uniform effect across all firms, which means that changes in the supply of financing affects financially constrained firms disproportionally (e.g., Brown *et al.* 2009). Hence, firms' propensity to be affected by the FSAP amendments can be determined by their ex-ante level of financial constraints.

In the main specifications, firms are categorized as financially constrained (or not) based on their pre-FSAP value of the S&A index (see Hadlock and Pierce 2010). The index predicts constraints as a function of firm size and age and has the advantage to be applicable for a broad set of firms. Importantly, unlike other indices (such as the Kaplan-Zingales or the Whited-Wu index), it can be calculated for small private firms, which constitute the majority of sample firms. As literature raises doubts on the precision of globally applied measures of financial constraints (e.g. Farre-Mensa and Ljungqvist 2016), the analysis does not rely on marginal differences among scores but instead, rather uses broader classifications. More specifically, firms below (above) the country-specific ex-ante median S&A value are considered as financially constrained (unconstrained). Robustness checks test the sensitivity of this classification thresholds. Importantly, firms are categorized based on their pre-integration specifications, as estimates might be confounded if the variation in financial constraints is endogenous to unobserved variation in firm borrowing. Given that the FSAP is a plausibly exogenous event, firms properties regarding financial constraints should be exogenous as long as the integration process is not initiated.

While generally all firms are exposed to the FSAP amendments, financial integration should relax financing constraints especially for firms with insufficient internal funds and higher financing costs (e.g., Holmström and Tirole 1997). Hence, my identifying assumption is that financially constrained firms are disproportionally affected by the exogenous shift in market conditions. Consistent with corporate finance literature (e.g., Fama and French 2002), summary statistics in Table A4 (Appendix E) indicate that exposed firms indeed face higher costs of obtaining loans (*interest burden*), have fewer collateral available (*tangibility*), a shorter track record (*age*), and lower bank debt (*bank loan ratio*).

The panel structure of the data enables controlling for unobserved heterogeneity across firms and for country-specific time trends, such as cyclical patterns in borrowing conditions. I cluster standard errors by firms[11] in the main specification:

$$Invention_{it} = \beta_1(FI_{ct-1} \times Exp_i) + \beta_2 X_{it} + \beta_i + \beta_{ct} + \varepsilon_{it} \qquad , \tag{2}$$

where β_i and β_{ct} are firm- and country-year-fixed effects, respectively. X_{it} is a vector of control variables defined in A5 (Appendix E). $Invention_{it}$ resembles the inventive output of firm i in period t, which is one of the seven patent measures defined in Table 2. In the empirical analysis, I test different transformations of these variables to account for outliers and the skewness in the

[11] Results are not sensitive clustering standard errors by the country- or country-industry level.

distributions of most patenting dimensions. Exp_i is a dummy variable indicating whether a firm is considered as ex-ante financially constrained (=1) or not (=0). The coefficient of interest, β_1, captures the (local) average treatment effect on the exposed firms and displays the causal effect of financial integration on firm-level patenting behavior for that particular subgroup. Note that perfect multicollinearity would arise from including respective fixed effects. Therefore, the single regressors of the interaction term are omitted in Equation (2). In line with previous analyses, I assume that the treatment affects inventive outcomes with a time lag (Kalemli-Özcan *et al.* 2013, Christensen *et al.* 2016). To further account for the right-skewed distribution and the issue of many zero observations in firm-level patenting activities, the main analysis also includes Poisson pseudo quasi-maximum likelihood regressions as described by Correia *et al.* (2020). In Appendix D, DID the parallel trend assumption is discussed and tested.

4 Empirical results

4.1 Baseline results

Table 4 displays results from different variants of the baseline specification (Equation 2) using patent filings as dependent variable. Across specifications, the coefficient of interest is positive and significant at the 1 percent level suggesting that the introduction of the FSAP has a positive disproportional effect on the number of patent filings of ex-ante financially constrained firms. Using Poisson pseudo quasi-maximum likelihood (PQML) estimations with multiple levels of fixed effects (see Columns V-VIII) does not affect the findings. Results are robust to the use of different definitions of the dependent variable (see Table A6 in Appendix E) and economically significant in magnitude: The main specification (Column III) suggests that moving the average firm from the pre- to the post-integration period results in a 44% higher increase in annual patent filings (i.e. about 3 patents per year) for ex-ante financially constrained firms compared to control group firms. Moreover, changing the cutoff threshold to higher S&A index scores illustrates that this effect becomes stronger for more financially constrained firms (see Figure A3 in Appendix F). Evidently, these observations suggest that relaxing financing constraints has a stimulating effect on the quantity of patents.

- Insert Table 4 here -

I repeat the estimation specifications using the patent quality dimensions as dependent variables. Figure 2 summarizes the main findings of the baseline estimations graphically while Tables A7 and A8 (in Appendix E) display results in more detail. In contrast to the effect on the quantity of patented inventions, the FSAP does not have a positive effect on the examined quality dimensions. This observation is consistent across all dimensions and specifications. To be more specific, estimations are statistically not different from zero or negative for proxies of technological quality (Columns I-IV, Table A7 in Appendix E), whereas the proxies of market value suggest a statistically significant negative effect (Columns V-VIII, respectively). The effects on market value are economically meaningful but much smaller compared to the impact on patent filings. For example, comparing pre- to post-integration periods implies an 8% larger decline in family size and a 28% larger decline in patent renewal rates for ex-ante constrained firms relative to the control group. Similarly, estimations explaining the effects of the FSAP on different types of patents (Table A8 in Appendix E) provide weak evidence of an increase in incremental patents, while the amount of patents with a high impact or a more general application decreases. However, effects are not robust to applying different sets of fixed effects. For consistency, I reestimate the regressions using PQML which does not affect the results (Table A9 in Appendix E).[12]

- Insert Figure 2 here -

All specifications use firm-specific annual *average* values of patenting measures which does not account for the specific distribution of these measures. This may be problematic, for example, because of the high skewness of patenting outcomes which implies that a rather small number of very influential patents drives technological progress. However, the occurrence of these few exceptional patents is not directly observable when considering average patenting values. To capture the effect on the upper bound of patent quality, I use firm-year maximum values as dependent variables (Table A10 in Appendix E). Results in Panel A show no effect on patents' technological quality but a statistically significant and negative effect on the value proxies. In Panel B, regressions use patent type variables as dependent variables. The maximum values of these binary variables indicate whether firms file at least one patent of a given type. Results suggest that patent types are generally not affected by the treatment with one notable exception, i.e. explorative patents. Consistent with the idea of financial slack triggering more risky innovative behavior (e.g. Almeida *et al.* 2017), the fraction of firms filing at least one explorative patent increases when experiencing better access to funding.

4.2 Testing the identification assumptions

This section tests whether the (de jure) measure of financial integration has quantifiable (de facto) effects. This provides evidence for the validity of the main identification assumption. Specifically, I analyze whether the FSAP affects firm's i) access to bank loans and ii) their subsequent use.

Before analyzing these two specific outcome variables, it is helpful to consider the mechanisms through which integration affects bank borrowing. By definition, a relatively more integrated market entails a more similar set of rules as compared to a relatively less integrated market.

[12] A set of (unreported) regressions shows that results are robust to i) varying the patenting measures (i.e. normalized by industry-year cohort values), ii) changing the lag specification of the financial integration measure, iii) weighting the financial integration measure based on the relative size (i.e. per capita GDP) of each country, iv) using alternative specifications of patent types, i.e. patent originality (Hall *et al.* 2001), and excluding German firms which comprise about one third of sample observations.

Similarly, integration removes (formal) barriers which pulls market entry. These changes in the competitive structure plausibly affect borrowing conditions on the firm level (e.g., Cornaggia *et al.* 2015). Moreover, the alignment of the legal framework facilitates the use of collateral for domestic and foreign firms (Liberti and Mian 2010). These aspects suggest that financial market harmonization puts downward pressure on interest rates and, ceteris paribus, increases demand for bank debt. Effects should be most pronounced for firms identified as ex-ante constrained, i.e. relatively small and young firms (Cetorelli and Strahan 2006).[13]

4.2.1 Financial integration and the use of bank loans

Figure 3 graphically illustrates changes in bank borrowing by comparing pre- and post integration levels for both ex-ante constrained and unconstrained (i.e. exposed and control group) firms. The graph in Panel A compares the share of firms that increase borrowing across groups. To detect economically important changes, I regard changes in bank loans as 'increases', if post-FSAP bank loan amounts are at least 10% higher than pre-FSAP amounts. The fraction of firms is significantly higher for ex-ante constrained firms (35.0%) than for unconstrained firms (20.3%; t-statistic: $t = 51.83$).[14] Further, the boxplot in Panel B displays the average changes in bank loans comparing pre- and post integration periods. The level of bank debt increases on average significantly more for exposed firms (14.8%) than for control group firms (5.7%; t-statistic: $t = 23.63$).

- Insert Figure 3 here -

Next, I test these findings in a multivariate setting. Table 5 displays estimates from regressions identical to the baseline setting but using firm bank loans as dependent variables. The coefficients of the interaction terms are positive and of highest statistical significance. Specifically, the coefficient of the interaction term in Column III suggests an economically meaningful additional increase of bank loans of 10% from pre- to post-FSAP implementation for ex-ante constrained firms relative to control group firms. Consistent with my classification approach, Table A11 (Appendix E) shows that increasing the threshold definition of financing constraints leads to even larger effects. Overall results are consistent with the identifying assumption by suggesting that ex-ante financially constrained firms, which account for the main findings on patenting outcomes, are able to disproportionally increase their use of bank debt.

- Insert Table 5 here -

[13] Amadeus contains data on the total amount of annual interest payments, allowing me to approximate firms' interest burden by the total interest charges during the year as a fraction of the average total debt of firm i at time t: $interest\ rate_{it} = interest\ expenses_{it}/[(total\ debt_{it} + total\ debt_{it-1})\ 0.5]$.

[14] Choosing an alternative threshold definition, consistently shows that 20.1% of exposed firms increase their bank debt by at least 25 percent, compared to only 8.0% of control group firms.

4.2.2 Financial integration and the costs of obtaining funding

Next, Table A12 (Appendix E) displays regression estimates explaining the impact of the FSAP on firms interest burden. Most importantly, the coefficient of the interaction term shows that the FSAP is associated with disproportionally lower interest burdens for exposed firms. The effect is statistically significant at the 1 percent level and holds across model specifications. The coefficient from the main specification in Column III suggests a 14.9% higher decrease in interest burden for the average treated firm compared to control group firms when moving from pre- to post-FSAP periods.

Results from these analyses show that firms defined as particularly exposed to the FSAP are indeed the ones that exhibit higher levels of bank loans and lower costs of borrowing. However, it does not directly show whether these two observations are actually connected. In Table 6, I thus analyze whether it is those firms which benefit from the change in law by lower interest burden that are actually the ones that increase borrowing. Comparing the coefficients of the interaction terms for firms that benefit from lower borrowing costs (Columns I and II) to those that do not benefit (Columns III and IV) clearly shows that the observed positive effect on bank borrowing is entirely driven by those firms that face a lower interest burden. Here, coefficients are large, positive, and highly significant, whereas coefficients are small and statistically not different from zero for firms with relatively high interest burden. Using triple interaction terms (Columns V and VI) provides equivalent results. Overall, these findings provide evidence on the validity of my identification assumptions and suggest that the FSAP enhanced borrowing activities by lowering the costs of loans, in particular, for previously constrained firms.

- Insert Table 6 here -

4.3 The timing of the effects

Due to the staggered nature of the treatment, it is necessary to thoroughly assess the timing of the effects. Plausibly, if firms adjust patenting activities in response to enhanced use of bank debt, the increase in debt-ratios should be quantifiable *before* the effects on patenting activities emerge. Testing this, Table 7 investigates the level at which the effect of financial integration on borrowing incurs. Coefficients are statistically insignificant for low cutoff levels of the integration measure but become larger and turn statistically significant for higher levels of integration (0.2 and 0.4). Importantly, these deviations in fact occur at already lower levels of integration compared to the deviation of patenting activities (see Columns V-VIII in Table 7).

- Insert Table 7 here -

Next, I analyze the lagged response of relaxed financing constraints on firm-level patenting in an event study design. In general, it takes time for firms to adjust their research activities in response to a shift in funding because of relatively high adjustment costs (Brown *et al.* 2009). Analyzing the time structure provides complementary insights which enable inferences about the persistence of the effects of financial market integration. Because of the staggered FSAP implementation, it is intuitive to analyze its impact based on the integration phase and not on (country-specific) years relative to specific treatment dates. Hence, the event study design deploys interactions between the treatment indicator and country-specific dummies reflecting different stages of the integration process. Specifically, the analysis distinguishes between pre-treatment ($FI_{ct} = 0$), early stage ($0 < FI_{ct} < 0.5$), late stage ($1 > FI_{ct} > 0.5$), and post-treatment ($FI_{ct} = 1$) periods using the pre-treatment stage of financial integration as reference period. The regression reads as follows:

$$Y_{it} = \alpha_{\text{stage}}(FI_{ct}^{\text{stage}} \times Exp_i) + \alpha X_{it} + \alpha_i + \alpha_{ct} + u_{it} \, , \tag{3}$$

where Y can denote either a patenting measure or firms' borrowing activities. *Stage* refers to the four previously defined integration stages, i.e., pre-integration, early, late, and post-integration. The remaining variables are defined as Equation (2).

- Insert Figure 4 here -

Figure 4 graphically illustrates the results of this approach for both the firms' patent filing and borrowing activities, and provides several important insights. First, in the early phase of the integration period, there are no statistically significant effects on patent filings. Second, using firms' borrowing activities as dependent variable shows positive and statistically significant effects already in the early integration stage. Hence, the positive effect on bank borrowing unravels earlier than the positive effect on patent filings – an observation illustrated more granularly in Figure A4 (Appendix F). Third, in the later phase of integration, both coefficients increase further in magnitude, are highly statistically significant, and are most sizable for the post-treatment period.

Turning next to the dimensions of patent quality, the regressions are repeated by using the early stage of integration as reference period. Across all specifications, results displayed in Figure A5 (Appendix E) show negative coefficients of the interaction terms of late stage and post-treatment.[15] While this pattern is again persistent, the rather weak statistical power allows only to claim a modest negative effect of the treatment on the quality dimensions.

Overall, assessing the effect of financial integration in this way uncovers that early and late integration phases seem to differ in a distinct manner. The treatment is already initiated during the early phases of financial integration from a *de jure* perspective, i.e., the financial integration measure (Equation 1) is larger than zero. However, *de facto*, effects on borrowing and patent filings are only quantifiable during the later phases of financial integration. To

[15]Only for incremental patents it is positive indicating more narrow patents.

investigate this aspect in more detail, I repeat the analysis on patent quality by slightly adjusting the event study regression. Now, the estimations includes equally sized stages between pre ($FI_{ct} = 0$) and post ($FI_{ct} = 1$) integration periods by splitting the FI measure into quintiles ($FI_{ct}^{Q} \in \{Q20, Q40, Q60, Q80, Q100\}$). To maintain a maximum information content, the last country-specific year in which $FI = 0$ is used as reference period. Results are displayed in Figures A4 and A5 (Appendix F) and mirror those from estimations on Equation () but provide some more insights. Notably, this specifications allows a more granular view, including an assessment on potential pre-trends. Coefficients for pre-treatment and the early integration phases do not differ relative to the last year before treatment occurs. This is consistent with the tests on anticipatory effects and provides further evidence in favor of the parallel trend assumption. Moreover, it appears that the positive effect on bank loans unfolds not in the beginning of the integration phase but still during the early stage ($FI_{ct} \in Q40$), whereas patent filings follows at the beginning of the late stage ($FI_{ct} \in Q60$).

Overall, results in this section suggest that financial integration becomes effective during the later integration period. This is reflected by higher bank loan rates, lower interest burden, and *subsequently* more patent applications. At the same time, patent quality starts to decline once patent filings increase. The results emphasize the absence of a positive effect on patents' quality dimensions associated with the treatment.

4.4 Threats to identification

4.4.1 Alternative factors: integration and macroeconomic conditions

While the previous tests analyze the timing of the treatment's impact, they cannot rule out that other contemporaneous (legal) events – which are unrelated to financial integration in the banking sector – trigger the same firm responses. Similarly, since the FSAP is implemented throughout several years of a business cycle, macroeconomic conditions may plausibly drive firm-level borrowing for a particular subgroup. In order to address these concerns, I repeat my analysis during an alternative sample time frame which is comparable with respect to macroeconomic conditions and financial integration but is not associated with improving access to bank debt.

The introduction of the Euro as bank money in 1999 fulfills these criteria for multiple reasons. First, macroeconomic conditions are comparable around the Euro- and the FSAP introduction: GDP rates follow a cyclical pattern including an early growth phase and a late phase of economic decline (see Figure A7 in Appendix F). Second, the introduction of the Euro marks one of the major elements of financial integration in the EU in the years preceding the FSAP. It causally increases intra-Eurozone investment by eliminating or at least significantly lowering exchange rate risk and other transaction costs (Haselmann and Herwartz 2010). Third, while fostering financial integration, the introduction of the Euro cannot be regarded as mitigating constraints in access to bank loans. For example, Haselmann and Herwartz (2010) find that the Euro did not effectively reduce information asymmetries between borrowers and lenders. Hence, the impact of the Euro's introduction on lending conditions for European firms should be much lower as compared to the effect of the FSAP's implementation.

The alternative setting is modeled such that financial integration takes place in 1999, the year the Euro became the official currency for Eurozone countries. While the FSAP is gradually introduced, the Euro introduction can be assigned to a specific date. To better imitate the FSAP, two placebo treatment variables are generated: i) a binary indicator equal to one after 1999 and ii) a continuous variable that mirrors the country-specific FSAP scores (Equation 1) with 1999 as the year in which the annual average FI score surpasses 0.5 for the first time. Effectively, the second measure implies shifting the FI measure five years back. I merge historical vintages from the Amadeus database covering the years starting with 1996 and remove the last four years (2005-2008) of the data to maintain a comparably symmetric time window around the treatment event. All variables are computed as before. For example, firms are classified as treated if the average pre-placebo-treatment S&A score is above the respective sample median.

- Insert Table 8 here -

Table 8 displays the regression estimates of this placebo event using patent filings and bank loans as dependent variables.[16] Estimations are statistically insignificant across specifications. Hence, the implementation of the Euro does not affect ex-ante constrained firms' innovative activities and borrowing behavior disproportionally. Importantly, the control variables (and the coefficients on the interaction term's single variables) have equal signs and are similar in size and statistical significance compared to baseline specifications (see Table 4). This suggests that the placebo sample is comparable to the main sample, i.e. it is unlikely that sample composition accounts for differences in the results. I confirm the robustness of these findings by showing that they are not sensitive to excluding non-Eurozone countries, using PQML estimations, and analyzing patent quality dimensions (see Tables A13, A14, and A15 in Appendix E). Despite marking a major event of financial market integration and similar macroeconomic conditions, this placebo event clearly does not mimic results obtained from the FSAP treatment. Results are consistent with the identifying assumptions and further strengthen the empirical strategy.

4.4.2 Plausibility test: Dependence on external finance

Next, I exploit firm-level heterogeneity regarding firms' access to funding as a plausibility check. To provide evidence on the relevance of the bank lending channel in my setting, I draw on the following logic: Informational asymmetries between borrowers and lenders increase the cost of external finance for inventive firms. This leaves firms with limited access to financial resources particularly dependent on fluctuations in the supply of external finance, such as bank debt.

[16] I apply the same regression variants as in the baseline case which does not change the main findings. To maintain a better overview, I omit the fourth specification which includes industry-year fixed effects.

Hence, firms with limited access to non-bank debt finance should disproportionally benefit from financial market integration. Consistent with my empirical strategy, the FSAP should not affect borrowing activities (and subsequently patenting) for firms that have other sources of external finance available irrespective of their ability to draw on internal sources. For identifying these firms, I adopt the idea of La Porta *et al.* (1997) stating that "*publicly traded firms get external debt finance in almost all countries, regardless of legal rules*" (p. 1148). Following this, public firms should not be as responsive to the treatment compared to private firms.

- Insert Table 9 here -

This proposition can be tested by re-estimating the main regressions on sample splits regarding whether a firm is publicly listed or not. Table 9 contains the estimates using bank loans and patent filings as dependent variables. Results show a clear pattern, that is coefficients for private firms are consistently positive and highly statistically significant across multiple variable definitions and model specifications, while none of the coefficients is statistically different from zero for the public-firm samples.[17] Moreover, coefficients of regressions using bank debt as dependent variable are also statistically insignificant. This finding is consistent both with my identifying assumption and with the view of La Porta *et al.* (1997) suggesting that public firms are immune to changes in the supply of external bank debt, because they can tap other sources of external finance.

4.4.3 Firm size and patenting activities

A natural argument that raises doubts on the validity of the main results is that effects are mainly driven by firms' lifecycle dynamics. Arguably, a firm which is considered as ex-ante financially constrained is, by definition, on average smaller than an unconstrained firm. For example, the circumstance that private firms (see section 4.4.2) plausibly are accountable for the main results already hints to the possibility that firm size is the actual determinant for the main results. Further, the FSAP implementation picks up a period of general economic growth. While the placebo test in section 4.4.1 addresses the concern of general macroeconomic trends, it does not per se rule out the possibility of small firms growth dynamics to be the primary driver for the main results.

The baseline specifications already account for these concerns to a certain degree. All estimations control for size either directly by including firm fixed-effects and size controls (i.e. the log of assets) separately or the change in size when using these controls together with the fixed effects.[18] Still, this subsection assesses the effects of firm size as a potential alternative mechanism in more detail. For this, Table A16 (Appendix E) displays estimations that include

[17] Results are similar in (undisplayed) regressions using patent quality proxies as dependent variables.

[18] Coefficients of the firm size control (log assets) in the baseline regression from Table 4 are positive and statistically significant both when including and excluding firm fixed-effects. Hence, the firm size as well as size growth are positively associated with respective firms' patenting activities.

information on the number of employees in a firm. In a similar fashion as the baseline regression, both the level and the interaction with the treatment indicator are included. If firm size is better able to explain the baseline results, coefficients of the DID estimator should become significantly smaller. There are two main insights. First, using different approximations of size indeed shows that firm size is positively associated with the general outcomes. This holds also for the interaction with the treatment variable. This insight is consistent with the notion that size is an important determinant for inventive activities. Second, the DID estimates remain virtually unchanged across all specifications.[19] This evidence speaks in favor of rejecting the hypothesis that firm size is better able to explain the main effects.

In sum, it is indisputable that firm size is an important determinant for patenting activities across firms and within firms over time. Several estimates document this link which emphasizes the need to account for firm size when estimating the effect of financial integration on borrowing and patenting activities. Most importantly for this analysis, the main results remain unchanged even after controlling for firm size in various ways.

4.5 On the empirical mechanisms

4.5.1 Does increased funding affect research strategies?

The following analyses are intended to provide a better understanding on the mechanisms behind the main results. For example, according to the empirical approach, firms should use additional funding (at least partially) to increase investment in inventive activities. First, I therefore try to establish a link between borrowing and patenting by providing evidence on the actual use of additional bank debt. If firms indeed change their patenting behavior because of relaxed financing constraints, additional debt should be positively associated with expenditures on patenting.

To study this relationship, data on firm-level annual patenting expenses from Gill and Heller (2020) are used. They include application, grant, and renewal fees out of which the annually obligatory renewal fees typically account the major share (de la Potterie 2010).[20] While administrative fees vary substantially worldwide, these costs are relatively high in the European patent system (Harhoff *et al.* 2009), making expenditures particularly relevant for sample firms. In my setting, patenting expenditures can thus be expected to resemble a meaningful fraction of firms' research budgets. Consistent with this, Figure A8 (Appendix F) graphically displays the strong positive relationship between expenditures on research and development and patenting costs.[21]

- Insert Table 10 here -

[19] Undisplayed regressions show that these results hold when considering changes in firm size by controlling for firm fixed-effects.

[20] Notably, this approach goes beyond adding up filing fees which would be comparable to a linear transformation of filing counts: If one patent filing x costs c, $x + y$ patent filings cost $(x + y)c$.

[21] Though generally possible, alternatively using research and development (R&D) data would largely reduce my sample size, as these information are only available for 3% of observations compared to 20% for patent expenditure information. Related to this, using R&D data biases the sample towards large public firms, since these data are commonly obtained from annual reports.

Table 10 displays regressions estimating the FSAP's effect on firm-level patenting expenditures in two distinct ways. In Panel A, the dependent variable is the share of patent expenditures to total assets, which captures firms' patenting intensity. Positive and statistically highly significant coefficients across specifications suggest that financial integration induces exposed firms to disproportionally increase their patenting intensity by means of higher expenditures. Hence, firms, which are associated with higher debt ratios and more patent filings, also extend their spendings on patenting. Panel B uses firm's patent expenditures relative the amount of bank debt outstanding as dependent variable. Coefficients are positive but statistically insignificant across specifications.[22] Hence, firms do not appear to intensify patenting activities relative to other potential investments. Instead, the increase in patenting expenses is proportional to the increase in bank debt suggesting a relatively stable patenting budget. This finding is consistent with my identification strategy suggesting that firms use additional debt for patenting expenses. However, firms do not appear to respond to relaxed financing constraints by adjusting their overall research strategies. This might be one potential reason why baseline effects on patent quality dimensions are relatively weak.

4.5.2 On the disciplining effect of financial constraints

The pattern of an average decline in patent quality resulting from relaxed financial constraints is consistent with the notion of a disciplining effect of resource scarcity (Aghion *et al.* 2013). However, the main results so far do not answer two central aspects. First, average effects do not imply that the negative findings on patent quality equally apply for all firms. Second, economic theory allows for multiple interpretations about how the decline in patent quality can be explained. In this subsection, I therefore establish a central mechanism behind the main results which highlights potential disciplining effects and uncovers heterogeneity behind the overall results.

If sufficient resources are not available, financially constrained firms have to forgo some promising research projects (Hottenrott and Peters 2012), which induces them to rationally implement the projects of highest expected value first. Alleviating these constraints might cause firms to work on inventive projects of relatively lower quality out of their set of alternatives as long as these projects have a positive net present value. A priori, it is not clear which firms are specifically prone to this. For example, if firms already implemented all of their most valuable projects, enlarging their patent portfolio comes at the cost of adding patents of relatively lower quality to their portfolio. In this case, the decline in patent quality results from decreasing returns to investment in inventive activities (Lokshin *et al.* 2008). Plausibly, the effect of decreasing returns to investment should be observed particularly for firms with a relatively high patenting intensity ex-ante. Alternatively, it is possible that the expansion of relatively

[22] Despite a relatively similar size in absolute terms, relative to the mean dependent variable, the coefficient is much smaller in Panel B (mean: 0.061) as compared to Panel A (0.008).

less patenting-intensive firms might cause patent quality to decrease. High opportunity costs to patenting might have previously crowded out these firms. Relaxing financing constraints lowers the opportunity costs and thus may induce those firms that initially only had few patenting projects to file more patents.

To study potential disciplining effects, I thus distinguish between high and low patenting intensive firms. I consider patenting costs as determinant for the ex-ante patenting intensity (see Section 4.5.1) in order to account for i) the relatively short pre-treatment period in the sample and ii) the fact that firms might not file many patents during this time despite holding a one or more patents. This approach allows capturing firms' actively held patent portfolios, disregarding a potential absence of patent filings. Specifically, firms are defined as high (low) patenting-intensive if they have above (below) average patenting expenses for the country-specific years in which $FI < 0.2$. Importantly, ex-ante patenting intensities do not explain firms' propensity to be affected by the treatment. Table A17 (Appendix E) shows that both types of firms similarly benefit from the FSAP by increasing their bank debt ratios. At the same time, both firm types increase the number of patent filings, while the increase relative to the mean is about twice as high for firms with high ex-ante patenting intensity (see Table A18 in Appendix E). Comparing changes in patenting expenditures from pre- to post-treatment shows that the increase in expenditures is much stronger in relative terms for ex-ante low patenting intensive firms (see Table 11). This is consistent with the classification of the two categories and potentially suggests that there is a catching up process in patenting intensities between them.

- Insert Table 11 here -

To determine the underlying economic mechanism, it is central to analyze heterogeneous treatment effects for high and low ex-ante patenting-intensive firms regarding patent quality. Figure 5 summarizes the findings graphically.[23] For ex-ante patenting-intensive firms, the effect of FSAP on patent quality dimensions is negative across specifications which confirms baseline results (Section 4.1). In fact, results are even more pronounced suggesting that the average patenting-intensive firm files patents of relatively lower quality. An additional finding which was previously disclosed in the main results is that firms with ex-ante low patenting intensity exhibit *higher* average patent quality. Despite suffering from low statistical power, results persist across specifications and stand in stark contrast to findings of firms with higher ex-ante patenting intensity. I repeat the analysis for maximum values using patent types as dependent variables (Table A21 in Appendix E).[24] Estimates suggest that ex-ante low patenting-intensive firms increase their propensity to file patents on explorative and high impact inventions.

- Insert Figure 5 here -

[23] Table A19 (Appendix E) contains the corresponding estimation results

[24] Unreported estimates using patent quality dimensions do not provide further insights.

In order to further investigate potential disciplining effects, I test whether financial resource are invested efficiently by computing the patent quality variables as a fraction of patenting expenses.[25] To account for the fact that patenting expenses and quality measures potentially vary significantly across industries, I use both regular ratios and those normalized by the industry-year-specific maximum. Table A21 (Appendix E) shows that for the subset of high ex-ante patenting firms coefficients of the quality proxies are negative across specifications and statistically significant in the case of forward citations. In contrast, coefficients are positive but insignificant for firms with low ex-ante patenting intensities. These findings suggest that the average (quality-)return to investment diminishes for firms that already patent frequently and thus can be expected of having realized their most valuable projects. The disciplining effect of financing constraints appears to play a role with respect to the efficient use of financial resources. Even for firms that increase their patenting quality, there is no significant efficiency gain.

In sum, these analyses uncover several important insights. The effect of decreasing returns on investment in inventive activities can explain the main effects, i.e., the modest average decline in patent quality. In particular, firms with ex-ante high patenting intensity increase their propensity to file patents that protect incremental and less technologically diversified inventions. For these firms the removal of financial constraints can be plausibly interpreted as inducing financial slack, because they were able to patent intensively despite being financially constrained. This aspect speaks in favor of the hypothesis that financial constraints serve as a disciplining devise for this subset of firms prior to the treatment. At the same time, the removal of financing constraints has beneficiary outcomes for firms that might have not yet exhausted their inventive capacity: For relatively less patenting intensive firms, relaxing financing constraints has both, a positive effect on the quantity and the quality of patenting activities while enhancing their propensity to file more explorative and high impact patents. These findings are consistent with the idea that financial resources are key input factors for enabling initial commercialization of inventions (Nanda and Rhodes-Kropf 2016). Better access to funding appears to release previously unexploited inventive potential embodied in some financially constrained firms.

5 Conclusion

Studies on the effects of finance as a key input factor for inventive activities commonly show a positive effect of financial resources on inventive output (Brown *et al.* 2009, Chava *et al.* 2013, Acharya and Xu 2017). In contrast, another strand of literature identifies potential benefits resulting from the scarcity of financial resources (Ederer and Manso 2013, Aghion *et al.* 2013, Almeida *et al.* 2017). Linking these two perspectives, I examine the impact of relaxed financial constraints induced by European financial market integration on firm-level inventions regarding

[25] For consistency, I only estimate effects on those variables that are not directly affected by patenting expenditures, i.e. patent renewals and family size.

the quantity and quality of patents.

Using a difference-in-differences setting, I find that relaxing financing constraints has a strong positive effect on the quantity of firms' patenting activities. Moving the average affected firm from the pre- to the post-integration period results in a more than 40% increase in patent filings (i.e. 3 patents per year) relative to a control group. At the same time, however, I do not find evidence for positive effects on patent quality along a very wide set of tested dimensions. Instead, there is a weak but persistent negative effect for the average treated firm.

To obtain these results, I exploit the Financial Services Action Plan – a major initiative by the European Commission to enhance financial integration – as an identifying event. Estimations show that banking-related amendments stimulate firms' access to financial resources, i.e., lower interest burden and increase the use of bank debt. Subsequent analyses underline that results are unlikely to reflect general macroeconomic conditions or time trends. Thus, the analysis provides evidence on the importance of public policies in supporting firm-level financing conditions.

Importantly, I am able to study potential mechanisms behind the main results by exploring heterogeneity in my large-scale sample, including mostly small and medium-sized firms across multiple countries and industries. For firms with a relatively high pre-treatment patenting intensity these effects are strongest. For example, the negative effects on patent quality are much more pronounced. This is consistent with the idea of decreasing returns to investment in inventive activities. Since rational firms first undertake their most promising research projects, improved access to external funding induces patenting intensive firms to add patents to their portfolio which are of lower average quality compared to their existing stock. Notably, the reverse is true for firms with low ex-ante patenting intensities. Here, effects on patent quality are positive which implies that mitigating financing constraints helps them to initiate commercialization and diffusion of their inventive output.

In sum, this study suggests that access to finance is a crucial determinant of inventive activities and that alleviating financial constraints helps to spur firms' patenting activities. However, heterogeneity in the results shows that the impact of financing constraints on inventive activities is more complex as commonly suggested. This entails novel insights for governmental and business policies that primarily target monetary aspects to enhance research activities. Different outcomes regarding the quantity and quality of inventive output highlight the importance of acknowledging both dimensions when evaluating the efficient allocation of research spendings.

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Tables from the main part:

Table 1: Sample distribution across countries

Country	Obs.	(in %)	Firms	(in %)	Patents	(in %)
Belgium	7,455	(5.95)	1,307	(5.28)	25,493	(3.85)
Denmark	6,174	(4.93)	1,149	(4.65)	26,427	(3.99)
Finland	9,370	(7.48)	1,709	(6.91)	23,902	(3.61)
France	39,878	(15.02)	6,630	(22.91)	193,241	(29.15)
Germany	18,820	(31.83)	5,667	(26.80)	222,068	(33.49)
Ireland	236	(0.19)	104	(0.42)	1,119	(0.17)
Italy	1,220	(0.97)	203	(0.82)	1,381	(0.21)
Netherlands	2,995	(2.39)	686	(2.77)	31,139	(4.70)
Sweden	16,105	(12.85)	2,782	(11.25)	61,080	(9.21)
United Kingdom	23,047	(18.39)	4,499	(18.19)	77,145	(11.64)
Total	125,300	(100.00)	24,736	(100.00)	662,995	(100.00)

Notes: The table displays the distribution of firm-year observations in the main sample across different countries and the corresponding absolute number of firms and patents behind these observations. Parentheses next to respective values indicate the corresponding shares as fractions of column totals.

Table 2: Definitions of patenting dimensions

Category	Name	Definition
Quantity	**1)** Patent filings	The sum of all patent applications within a year
Quality	**2)** Forward citations	Citations received within 7 years after filing
	3) Claims	Number of claims as fraction of referenced patents
Value	**4)**Family size	Number of (EPC) countries at which a patent is kept active on average
	5) Renewals	The number of annual patent renewals starting with the third year after filing
Patent types	**6)** Incremental patent	Both criteria have to be fulfilled: i) Not a high impact patent (*a*) ii) Not a high scope patent (*b*)
	7) Explorative patent	Both criteria have to be fulfilled: i) High impact patent (*a*) ii) High scope patent (*b*)
	a) High impact	3 out of 4 criteria have to be fulfilled: i) Positive number of forward citations ii) > average forward-backward citation ratio iii) > average claims-backward citation ratio iv) > 80% A-type references
	b) Technological diverse	Two relevant criteria fulfilled: i) > average patent scope ii) > average patent-industry concentration index

Table 3: Summary statistics, patenting and firm characteristics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Panel A: Firm characteristics					
Firm size (log. assets)	125,300	8.825	2.473	1.946	13.891
Tangibility	125,300	0.205	0.211	0	1
Cash-flow ratio	125,300	0.070	0.182	-0.648	0.561
Profitability (RoA)	125,300	0.061	0.135	-0.434	0.434
Debt ratio	122,231	0.614	0.242	0	1
Bank loan ratio	113,664	0.238	0.207	0	0.982
Interest rate	92,124	0.073	0.080	0.001	0.201
Age	124,743	25.673	24.436	0	125
Quoted (share)	125,300	0.047	0.212	0	1
Panel B: Patent variables					
1) Nr. of patents filed	125,300	5.291	44.167	0	2987
2) Forward cits. (7-yr.)	42,401	1.787	4.251	0	243
3) Claims-ratio	42,401	0.483	1.181	0	63
4) Family size	42,401	4.333	3.176	1	37
5) Renewals	42,401	0.571	1.322	0	18
Renewals (non-zero)	17,725	11.986	3.099	1	18
Panel C: Patent types (indicators)					
6) Incremental	42,401	0.435	0.192	0	1
7) Explorative	42,401	0.020	0.096	0	1
High impact	42,401	0.061	0.168	0	1
Tech. diverse	42,401	0.280	0.360	0	1

Notes: The table displays summary statistics on firm characteristics (Panel A) and several measures of patenting activities (Panel B and C). Financial variables from Panel A are defined in Table A5 (Appendix E). All patenting variables reflect average firm-year values of firms' entire patent portfolio. Patenting variables are defined in Table 2. Variables indicated with a number (1-7) resemble the set of dependent variables used to measure patent quantity, quality, values, and types in the baseline regressions.

Table 4: Baseline regression results: financial integration and patent filings

Dependent variable:	Patent filings							
Model:	OLS				PQML			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × Exposure	2.543***	3.202***	3.142***	3.723***	0.269**	0.426***	0.404**	0.427**
	(0.956)	(1.033)	(1.035)	(1.214)	(0.109)	(0.052)	(0.051)	(0.049)
FI	-0.447	-0.415			-0.521***	-0.057		
	(0.717)	(0.793)			(0.158)	(0.045)		
Exposure	6.085***				0.635***			
	(0.687)				(0.055)			
Log. assets	2.142***	0.938**	0.957**	0.978**	0.516***	0.145***	0.164***	0.165***
	(0.194)	(0.456)	(0.461)	(0.465)	(0.010)	(0.024)	(0.024)	(0.024)
Tangibility	8.876***	7.938***	7.721***	7.825***	0.629***	0.620***	0.552***	0.570***
	(2.398)	(2.868)	(2.848)	(2.876)	(0.105)	(0.084)	(0.084)	(0.087)
Cash-flow	-0.651***	-0.266	-0.260	-0.181	-0.475***	-0.082	-0.105	-0.075
	(0.180)	(0.249)	(0.250)	(0.181)	(0.155)	(0.069)	(0.066)	(0.064)
Profitability	0.901***	0.281	0.270	0.204	1.199***	0.049	0.034	0.037
	(0.240)	(0.285)	(0.285)	(0.288)	(0.163)	(0.066)	(0.063)	(0.062)
Constant	-20.551***	-4.280	-5.671	-8.783	-4.547***	3.096***	2.059***	2.038***
	(3.805)	(5.053)	(4.422)	(6.068)	(0.494)	(0.371)	(0.300)	(0.298)
Additional controls:								
Macro-level	Yes	Yes	No	No	No	Yes	No	No
Industry-FE	Yes	No	No	No	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Country-Year-FE	No	No	Yes	Yes	No	No	Yes	Yes
Industry-Year-FE	No	No	No	Yes	No	No	No	Yes
Observations	125,300	125,300	125,300	125,300	79,923	79,923	79,923	79,923

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on the number of firms' annual patent filings. The main variable of interest is the coefficient on the interaction of FI and $Exposure$. Columns I-IV show results of fixed-effects panel regressions, while Columns V-VIII repeat those specifications using Poisson pseudo quasi-maximum likelihood (PQML) regression with multiple levels of fixed effects. In the latter case 40,967 observations are dropped that are either singletons or separated by a fixed effect. Columns III and VII are the baseline specifications as defined in Equation (2). To control for unobserved firm-, country-, industry, and time-specific heterogeneity, regressions include respective fixed effects, as indicated in the table. The omission of macro controls, coefficients on FI_{ct} and Exposure is due to perfect collinearity arising from the inclusion of the fixed effects in respective columns. Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 5: Panel regression results: financial integration and bank borrowing

Dependent variable:	Bank debt (log.)			
	(I)	(II)	(III)	(IV)
FI × Exposure	0.133***	0.099***	0.101***	0.074**
	(0.027)	(0.028)	(0.028)	(0.029)
FI	0.205***	-0.067*		
	(0.037)	(0.038)		
Exposure	-0.039			
	(0.028)			
Log. assets	0.913***	0.830***	0.828***	0.827***
	(0.005)	(0.015)	(0.015)	(0.015)
Tangibility	0.214**	0.355***	0.323***	0.322***
	(0.054)	(0.075)	(0.074)	(0.073)
Cash-flow	-0.725***	-0.589***	-0.593***	-0.597***
	(0.030)	(0.033)	(0.033)	(0.033)
Profitability	0.054*	0.053*	0.053*	0.055*
	(0.031)	(0.032)	(0.032)	(0.032)
Constant	-0.816***	-0.722***	-0.604***	-0.239
	(0.220)	(0.180)	(0.135)	(2.190)
Additional controls:				
Macro-level	Yes	Yes	No	No
Industry-FE	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes
Country-Year-FE	No	No	Yes	Yes
Industry-Year-FE	No	No	No	Yes
Observations	113,664	113,664	113,664	113,664

Notes: This table presents OLS estimates from fixed-effects panel regressions explaining the effect of financial integration on the use of bank loans measured by the logarithm of bank debt. The main variable of interest is the DID estimator, i.e. the interaction of FI_{ct} and $Exposure$, as defined in Equation (2); additional control variables are defined in Table A5 (Appendix E). To control for unobserved firm-, country-, industry, and time-specific heterogeneity, regressions include respective fixed effects, as indicated in the table. The omission of macro controls, coefficients on FI_{ct} and Exposure is due to perfect collinearity arising from the inclusion of the fixed effects in respective columns. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 6: Panel regressions: beneficiaries and bank borrowing

Dependent variables:	Bank debt (log.)					
Firms' borrowing conditions	Improved		Worsen		All	
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × Exp. × Beneficiary					0.215***	0.226***
					(0.050)	(0.055)
FI × Exposure	0.196***	0.137***	-0.014	-0.033	-0.019	-0.065
	(0.043)	(0.042)	(0.049)	(0.050)	(0.043)	(0.045)
Exposure	-0.169***		-0.145***		-0.159***	
	(0.038)		(0.042)		(0.028)	
FI	0.006		0.023		0.020	
	(0.052)		(0.057)		(0.038)	
Additional controls:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes	No	Yes
Observations	45,406	45,406	35,150	35,150	80,556	80,556

Notes: This table presents estimates from panel regressions explaining the impact of financial integration on the use of banks according to whether firms benefit from integration in terms of lower interest burden. Regressions are repeated baseline regressions on sample splits using i) firms which face lower interest burden comparing post- to pre-treatment periods (Columns I-II), ii) firms which face higher interest burden (Columns III-IV), and iii) the full sample. In the full sample, regressions additionally include a triple interaction of the DID estimator (Equation 2) multiplied with an indicator on whether a firm faces lower interest burden comparing post- to pre-treatment periods. Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 7: Anticipatory effects of borrowing and patenting activities

Dependent variable:	Bank debt (log.)				Patent filings			
Pre-treatment period definition (FI):	=0	<0.1	<0.2	<0.4	=0	<0.1	<0.2	<0.4
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Exposure × Trend	0.019	0.016	0.025**	0.026***	0.441	0.154	0.214	0.186
	(0.014)	(0.012)	(0.010)	(0.009)	(0.411)	(0.367)	(0.316)	(0.266)
Trend	0.001	-0.015	0.013	0.012	-0.463	-0.389	-0.200	-0.116
	(0.035)	(0.027)	(0.013)	(0.014)	(0.346)	(0.305)	(0.169)	(0.150)
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30,040	34,405	50,529	57,724	32,981	37,380	55,177	63,135

Notes: This table presents estimates from regressions explaining the use of bank loans and tests for the presence of trends during the pre-treatment period. Pre-treatment is defined according to different levels of the financial integration measure (Equation 1): 0 (Columns I and V), 0.1 (Columns II and VI), 0.2 (Columns III and VII), and 0.4 (Columns IV and VIII). The dependent variables are the logarithm of bank loans (Columns I-IV) and patent filings (Columns V-VIII). Regressions control for confounding factors as defined in Table A5, firm fixed-effects and include the following two terms: i) a trend variable which is a running number for each year and ii) an interaction term of the trend variable with the exposure variable indicating whether a firm belongs to the treatment group or not (see Section 3.3). Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 8: Placebo regressions: financial market integration and patenting

Dep. variables:	Patent filings						Bank debt (log.)					
Treatment variables:	Binary			Continuous			Binary			Continuous		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)
$FI^P \times$ Exposure	0.544	0.794	0.585	0.467	0.701	0.369	0.019	0.011	-0.008	0.065*	0.056	0.036
	(1.209)	(1.236)	(1.115)	(1.400)	(1.441)	(1.295)	(0.029)	(0.029)	(0.032)	(0.036)	(0.036)	(0.039)
FI^P	-0.440	-0.234		-1.142	-1.184		0.088***	0.008		0.153***	0.009	
	(0.450)	(0.441)		(0.787)	(0.776)		(0.025)	(0.025)		(0.050)	(0.057)	
Exposure	9.348***			9.501***			-0.111***			-0.138***		
	(1.360)			(1.296)			(0.039)			(0.040)		
Log. assets	3.406***	2.323*	2.153	3.404***	2.339*	2.154	0.922***	0.910***	0.876***	0.922***	0.909***	0.875***
	(0.561)	(1.393)	(1.370)	(0.563)	(1.389)	(1.374)	(0.007)	(0.024)	(0.025)	(0.007)	(0.024)	(0.025)
Tangibility	9.242**	6.665	8.722*	9.257**	6.710	8.728*	0.522***	0.817***	0.585***	0.519***	0.815***	0.584***
	(3.698)	(4.554)	(4.666)	(6.312)	(7.394)	(7.602)	(0.084)	(0.117)	(0.131)	(0.084)	(0.117)	(0.131)
Cash-flow	-0.941*	-0.715	-0.783	-0.964*	-0.743	-0.789	-0.775***	-0.674***	-0.663***	-0.773***	-0.673***	-0.663***
	(0.538)	(0.697)	(0.670)	(0.539)	(0.698)	(0.673)	(0.050)	(0.052)	(0.054)	(0.050)	(0.052)	(0.054)
Profitability	1.351**	0.664	0.646	1.340**	0.653	0.644	0.002	0.014	0.003	0.002	0.014	0.002
	(0.558)	(0.705)	(0.708)	(0.562)	(0.707)	(0.717)	(0.053)	(0.054)	(0.056)	(0.961)	(2.402)	(2.365)
Constant	-31.465***	-10.312	-13.881	-34.030***	-13.576	-13.833	-1.036***	-1.370***	-0.897***	-1.036***	-1.370***	-0.897***
	(6.628)	(13.401)	(13.392)	(6.943)	(13.628)	(13.368)	(0.327)	(0.239)	(0.234)	(0.961)	(2.402)	(2.365)
Additional controls:												
Macro-level	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Industry-FE	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
Firm-FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Country-Year-FE	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Observations	49,966	49,966	49,966	49,966	49,966	49,966	47,320	47,320	47,320	47,320	47,320	47,320

Notes: This table presents estimates from panel regressions using an alternative treatment event for explaining the effect of financial integration on firms' annual patent filings (Columns I-VI) and on the use of bank loans (Columns VII-XII). Regressions are specified equivalent to the first three variants of the baseline estimations (see Table 4) but use a time window around the alternative treatment between 1997-2005. These specifications are repeated for the two outcome variables and for two different definitions of the placebo treatment (FI^P). Columns I-III and VIII-IX use a binary indicator as placebo treatment variable which equals one for all years after the implementation of the Euro in 1999. Columns IV-VI and X-XII use a continuous treatment variable which uses the country-specific values of the original FSAP financial integration measure (Equation 1) but shifted by five years such that the average FI score reaches 0.5 for the year 1999. Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 9: Plausibility test: Responsiveness to financial integration for private and public firms

Sample:	Private firms				Public firms			
Panel A:								
Dependent variables:	Bank debt (log.)		Bank-loan ratio		Bank debt (log.)		Bank-loan ratio	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × Exposure	0.121***	0.096***	0.023***	0.019***	0.029	0.080	-0.006	0.001
	(0.029)	(0.029)	(0.005)	(0.005)	(0.110)	(0.111)	(0.011)	(0.010)
FI	0.219***		-0.002		0.160		0.030**	
	(0.037)		(0.005)		(0.207)		(0.015)	
Exposure	-0.051*		-0.021***		-0.158		-0.011	
	(0.029)		(0.004)		(0.098)		(0.010)	
Panel B:								
Dependent variables:	Patent filings		Normalized filings		Patent filings		Normalized filings	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × Exposure	2.067**	2.549***	0.008***	0.011***	7.774	10.842	0.009	0.013
	(0.813)	(0.899)	(0.003)	(0.003)	(7.126)	(7.905)	(0.015)	(0.016)
FI	-0.508		0.002		0.224***		0.026	
	(0.600)		(0.002)		(0.068)		(0.021)	
Exposure	4.529***		0.032***		22.321***		0.087***	
	(0.611)		(0.002)		(4.621)		(0.015)	
Additional controls in Panel A and B:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes	No	Yes	No	Yes
Obs. (Panel A)	108,094	108,094	108,094	108,094	5,570	5,570	5,570	5,570
Obs. (Panel B)	119,373	119,373	119,373	119,373	5,927	5,927	5,927	5,927

Notes: This table presents estimates from OLS regressions testing heterogeneous treatment effects regarding the responsiveness of private and public firms to financial integration in terms of borrowing (Panel A) and patenting activities (Panel B), using two different variants of the baseline setup. Borrowing is measured by the logarithm of bank loans and the bank-debt to asset ratio, whereas patenting is measured by firms' annual patenting filings and the normalized values of patent filings. Normalization is achieved by relating each value to the industry-year-specific maximum value, i.e. $P^{\text{norm.}} = (\text{filings}_{it} / \text{max. filings}_{cnt})$ for firm i in country c, industry n, and time t. In both panels, the sample is split according to whether a firm is privately owned (Columns I-IV) or publicly listed (Columns V-VIII). All remaining specifications are as defined in the baseline estimations (e.g. Table 4). *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table 10: Financial integration and patenting expenditures

Panel A: Dependent variable:	Patenting expenditures to total assets ratio			
	(I)	(II)	(III)	(IV)
FI × Exposure	0.009^{***}	0.010^{***}	0.011^{***}	0.010^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
FI	-0.004	-0.003		
	(0.003)	(0.003)		
Exposure	0.019^{***}			
	(0.003)			
Panel B: Dependent variable:	Patenting expenditures to bank debt ratio			
	(I)	(II)	(III)	(IV)
FI × Exposure	0.011	0.014	0.016	0.011
	(0.016)	(0.017)	(0.017)	(0.017)
FI	-0.027^{*}	-0.016		
	(0.015)	(0.016)		
Exposure	0.082^{***}			
	(0.015)			
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Obs. (Panel A)	21,500	21,500	21,500	21,500
Obs. (Panel B)	19,378	19,378	19,378	19,378

Notes: This table presents OLS estimates from fixed-effects panel regressions estimating the effect of financial integration on patent expenditure measures. Panel A uses the ratio of patent expenditures to total assets ratio as dependent variable to proxy the patenting intensity of a firm. Panel B uses the ratio of patent expenditures to total bank debt capturing the fraction of patenting expenditures that are covered by external bank debt. Estimations use the same four variants and variable definitions as specified in the baseline setup (Table 4). *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

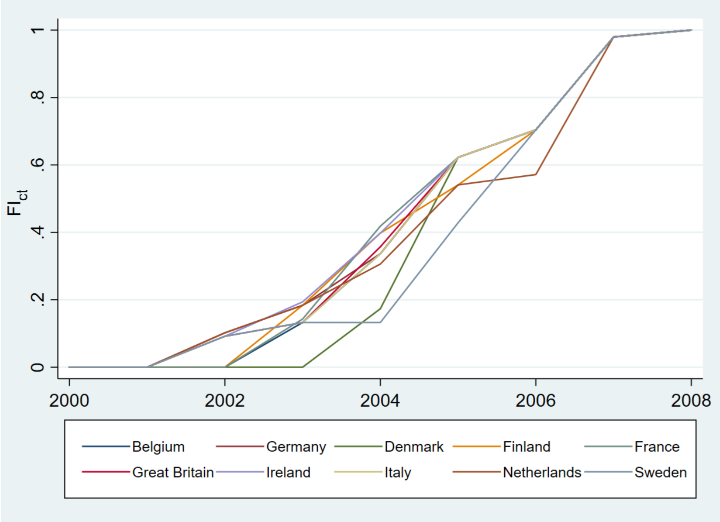
Table 11: Pre- and post integration patenting expenditures-to-asset ratios

	Patenting-ratios		
	Time frame		
Ex-ante patenting intensity:	Pre-treatment (FI<0.2)	Post-treatment (FI>0.8)	Difference in means
High	0.177	0.686	0.509^{***}
Low	1.592	1.973	0.380

Notes: This table presents mean values of firms' patenting intensities, i.e. patenting expenditures to asset ratios, before and after the treatment. It distinguishes among high and low ex-ante patenting intensive firms. Firms are categorized as high (low) depending on whether their pre-treatment specific mean value of patenting expenditures is above (below) the median value of all firms. Pre-(post-) treatment captures all years in which the integration measure (Equation 1) is smaller (larger) than 0.2 (0.8). The last column indicates the absolute difference in means and the corresponding level of statistical significance.

Figures from the main part:

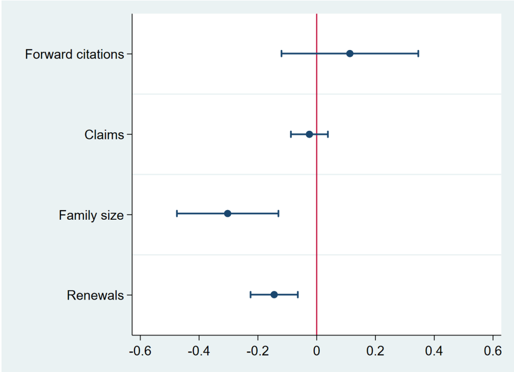
Figure 1: Treatment variable: FSAP integration measure (2000-2008)



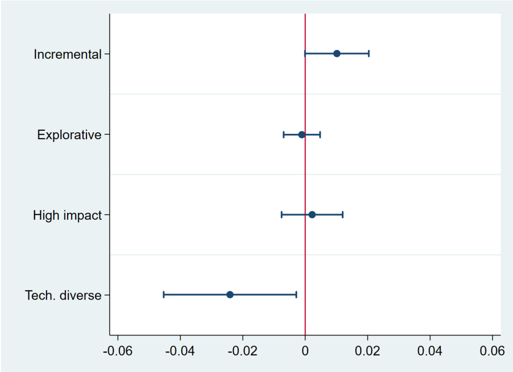
Notes: This figure plots the integration variable, FI_{ct} as defined in Equation (1) over the sample time frame, 2000-2008. Each color represents one of the sample countries. Values ranging between 0 and 1 indicate low (= 0) and high (= 1) multilateral adoption of FSAP Directives, i.e. financial market integration.

Figure 2: The effect of financial integration on patent quality dimensions

Panel A: Patent quality



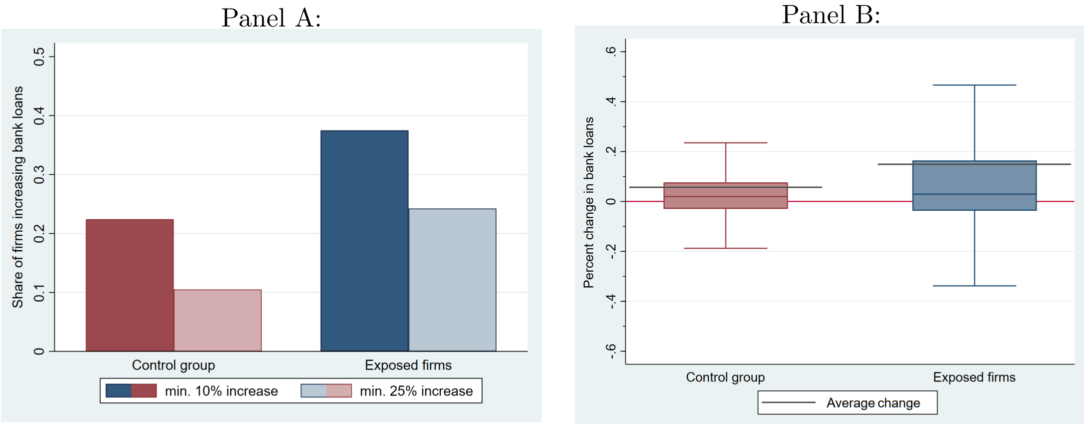
Panel B: Patent types



Notes: These two figures plot coefficients of the DID estimators deployed in fixed-effects panel regressions explaining the effect of financial integration on a set of different patenting outcomes. Regressions use the specifications from Equation (2) and deploy patent quality (Panel A) and patent type (Panel B) measures as defined in Table 2. Further details on the regressions and results from using different variants of these baseline outcomes are displayed in Tables A7 and A8. Whiskers span the 95 percent confidence intervals.

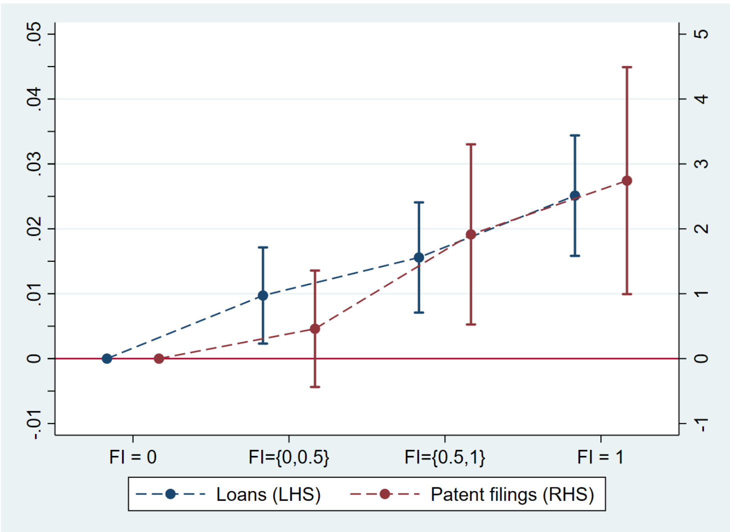
Figure 3: Changes in bank borrowing: pre- and post integration levels across firms

Panel A: Panel B:



Notes: These figures plot changes in bank borrowing of both treatment ('Exposed firms') and control group firms comparing pre- and post treatment periods, i.e. for country-specific years in which the financial integration measure (Equation 1) equals zero or one, respectively. In Panel A, bars show the fraction of firms that increase bank loans between pre- to post-FSAP periods. Dark (light) colors indicate whether firms increase their borrowing by at least 10 (25)%. In Panel B, the boxplots illustrate the relative change in bank loans (in %). The outer whiskers span the 25- and 75-percentiles. Dark lines within the bars are the group specific median; the gray line on top of the boxes displays the average change in bank loan levels.

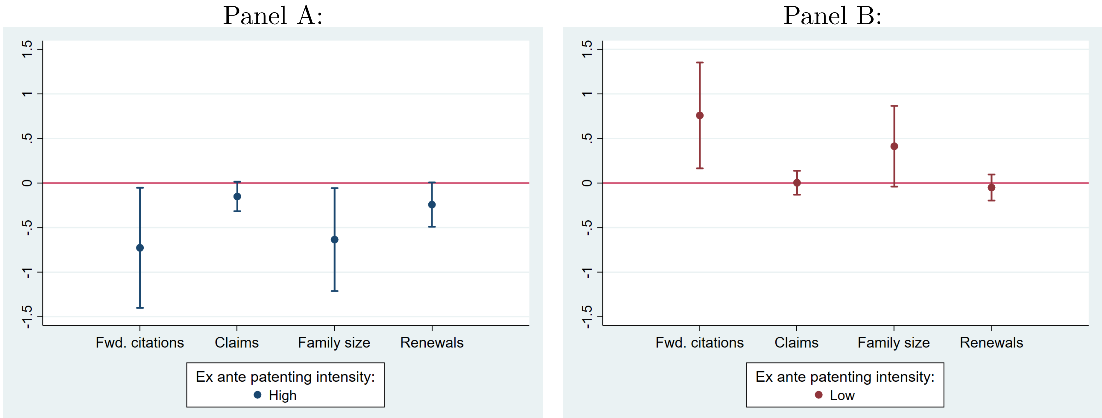
Figure 4: Timing of the integration effects on patent filings and use of bank debt



Notes: This graph illustrates the timing of the impact of financial market integration on borrowing and patenting activities by plotting DID coefficients using different stages of the integration process as interaction. The underlying regressions build on the main specification from Equation (2) but distinguish among four periods of integration: pre-treatment, low integration, high integration, and post treatment. Low (high) integration years are all country-specific observations with $FI < 0.5$ ($FI > 0.5$) except the pre- ($FI = 0$) and post-integration ($FI = 1$) years. The pre-treatment period is used as reference period. All variables are defined as in the baseline specification (Tables 4). Whiskers span the 95 percent confidence intervals.

Figure 5: Heterogeneous treatment effect: patenting intensities and patent quality

Panel A: Panel B:



Notes: These coefficient plots graphically illustrate heterogeneity in treatment effects distinguishing between firms according to their pre-treatment patenting intensities. The two graphs plot coefficients of the DID estimators deployed in fixed-effects panel regressions explaining the effect of financial integration on a set of different patent quality measures. Regressions use the specifications from Equation (2) and deploy technological quality and market value proxies as defined in Table 2. In Panel A (B), results on the subsample of firms with high (low) ex-ante patenting intensities are displayed. Patenting intensity refers to firms' total patenting expenditures during pre-treatment periods relative to the pre-treatment sample median. Whiskers span the 95 percent confidence intervals.

For Online Publication:

Appendix A : Related literature and contributions

First, this study contributes to literature on finance as a key input factor of inventive activities. For example, Nanda and Rhodes-Kropf (2016) suggest that financial markets actively drive inventive outcomes by enabling their initial financing, commercialization and diffusion. In general, negative shocks to the supply of external finance result in lower investment (Holmström and Tirole 1997). This effect is more pronounced for firms with high financing costs and strong dependence on external funding sources, such as firms engaged in research activities (e.g. Hall and Lerner 2010). Many empirical studies therefore emphasize that information asymmetries between innovative firms and investors make investment decisions of respective firms distinctively responsive to changes in funding (e.g. Hottenrott and Peters 2012, Hall *et al.* 2016). A common conclusion is that alleviating financing constraints induces firms to invest more in research and development and thereby increases innovative output (e.g. Brown *et al.* 2009, Chava *et al.* 2013, Acharya and Xu 2017). Going beyond concerns regarding asymmetric information, several characteristics of inventive activities place a special role on the actual source of finance.[26] Recent findings highlight the relevance of external debt providers for inventive activities (Kerr and Nanda 2015, Mann 2018), particularly the important role of banks (Robb and Robinson 2014, Chava *et al.* 2017) even for young start-ups (Hochberg *et al.* 2018, Hirsch and Walz 2019).

I combine these aspects with a second strand of literature which identifies agency issues affecting inventive activities, such as incentivizing effects that arise from the relative availability of funding. Limited amounts of funding can serve as a disciplining device by enforcing managers to optimize on investment decisions. Thus, input resource constraints can lead to a more efficient use of the existing set of deployable resources (Goldenberg *et al.* 2001, Gibbert and Scranton 2009), whereas removing these constraints may trigger wasteful investments (Aghion *et al.* 2013).

[26]Inventive activities are often enclosed in human capital, returns are uncertain and highly skewed (Kerr and Nanda 2015). In this context, firms' life-cycle stage strongly affects which specific source is most appropriate. Young start-ups commonly lack internal funds to undertake research and development. Venture capitalists help mitigating this issue by providing a combination of external capital, active involvement, and advice (Casamatta 2003). In contrast, relatively older firms commonly have more internal funds available to finance their activities and are more likely to provide assets as collateral.

Importantly, incentives are crucial for determining the type of inventions generated. Literature of cognitive psychology argues that financially unconstrained agents habitually acquire inputs needed for solving well-known, previously experienced problems (Scopelliti *et al.* 2014). Ederer and Manso (2013) similarly find that monetarily incentivized inventors create more ideas but these ideas are typically less explorative. In addition, monetary aspects shape quality features of inventive output on a firm level. To analyze this, some existing studies test the implications of major economic crises as adverse shocks on the access to finance and subsequent inventive behavior (e.g. Nanda and Nicholas 2014). Nanda and Nicholas (2014) show that the Great Depression in the US caused patenting activities to decline significantly, both in terms of quantity and quality. Moreover, the authors find an adjustment towards rather conservative, low risk and reward inventive activities. However, because these events have a strong disruptive effect on market participants' behavior, it may be difficult to disentangle whether changes in inventive activities are attributable to changes in financing conditions or to a reordering of the economic landscape. My approach differs from these studies in that it analyzes a recent policy agenda having heterogeneous effects on financing conditions across a large set of firms in the absence of disruptive contemporaneous events.[27]

A group of studies is most closely related to my analysis and investigates the effect of bank deregulations in the US during the 1980s and 1990s on firm-level inventions (Chava *et al.* 2013, Amore *et al.* 2013, Cornaggia *et al.* 2015). The authors assume deregulations to exogenously affect the supply of credit. They unanimously identify a positive relationship between improved access to funding and the intensity of inventive activities, predominantly focusing on standard measures (e.g. productivity, R&D spending, patent applications) all of which capture quantity dimensions of innovative output.[28]In order to expand the informative value of focusing on these dimensions (see Lerner and Seru (2017) for critique the use of these quantity dimensions), my analysis focuses on a broad set of value-relevant characteristics and types of inventions. Hence, I provide novel insights how financial constraints shape inventive activities along multiple patent-

[27]In the specific context of patenting, de Rassenfosse and Jaffe (2018) study a significant increase in patenting fees stipulated by the US Patent Law Amendment Act of 1982 and find higher costs to crowd out predominantly low-quality patents.

[28]One notable exception is that these authors also regard citation-weighted patent measures.

ing dimensions. These features allow highlighting the importance of appropriate funding for spurring inventive activities. At the same time, I am able to draw a more comprehensive picture regarding heterogeneous effects of relaxing financing constraints on firm-level inventions.

Finally, my analysis also contributes to literature on the impact of economic development (e.g. La Porta *et al.* 1998), specifically financial integration (Bertrand *et al.* 2007, Kerr and Nanda 2009), on real economic activity. One specific field investigates the impact of bank regulation from a legal perspective on credit availability and credit quality. Bank deregulation is associated with an increased sensitivity of bank-lending decisions to firm performance (Stiroh and Strahan 2003). Integration potentially helps reducing entry barriers, improving access to finance, and lowering interest rate spreads particularly for small firms (Cetorelli and Strahan 2006). My findings are consistent with these mechanisms by illustrating beneficial effects of market integration. Additionally, they consitute important insights regarding potential limitations of investment policies focusing on monetary input to support innovation.

Appendix B : Defining relevant patenting dimensions

Differentiating among patent quality and patent value is challenging. Ceteris paribus, a patent of higher technological quality should deliver higher value for the patentee. The reverse is not necessarily true, as some factors affect market value despite being unrelated to the quality of a patent. For instance, the size and regulatory framework of the respective market the patentee is located in affects the potential to extract value from a given invention (Aghion *et al.* 2015). However, these aspects are not directly related to the patent quality. In line with de Rassenfosse and Jaffe (2018), in my empirical setup I differentiate among factors that are both quality and value relevant as well as those that are only considered to be value relevant.

i) Measuring patent quality:

A well-known dimension of patent quality is forward citations. They refer to the number of citations a particular patent receives since it has been granted. Forward citation counts include references from patent equivalents, i.e. patent documents that protect the same invention at several patent offices (Webb *et al.* 2005). To assure comparability, I consider only the citations made within the first seven years after the publication date. The number of forward citations mirrors the technological importance of a patent for subsequent technologies and serves to indicate the economic value of inventions (Harhoff *et al.* 2003). A higher citation count therefore indicates higher patent quality in technological terms.

Yet, measuring patent quality exclusively by means of citations can be an issue, because their distribution is strongly skewed with most patents receiving zero or very few citations (de Rassenfosse and Jaffe 2017). I therefore additionally consider patent claims to be a relevant indicator for patent quality. According to the European Patent Convention (EPC 1973), patent claims "*define the matter for which protection is sought*" (Art. 84). Literature shows that claims reflect patents' technological breadth as they determine the boundaries of the exclusive rights of a patent owner, because only the technology covered in claims can be legally protected and enforced (OECD 2009). Thus, it approximates the size of the monopoly right attributed the patented invention.

ii) Value-related measures:

Literature points out that there are distinct measures related to the value of a patent. For example, the number of patent offices a patent is active at as well as the frequency of patent renewals signal patent value while not necessarily being related to its quality (Schankerman and Pakes 1986, Harhoff *et al.* 2003, de Rassenfosse and Jaffe 2018).

The first value measure considers the number of different patent offices at which a patent was filed, i.e. the so-called family size of a patent. According to the Paris Convention for the Protection of Industrial Property from 1883, inventors can apply for protection in any contracting states, once their patent application was approved (WIPO 2017). Protection in multiple countries is costly, because additional fees have to be covered at each patent office. Hence, willingness to incur these costs might resemble a higher underlying patent value. Several authors find the geographical scope of patents to be associated with patent value (Lanjouw *et al.* 1998, Harhoff *et al.* 2003, Squicciarini *et al.* 2013). I estimate the family size of a patent by counting the absolute number of patent offices at which the patent was filed throughout its lifetime.

Second, in order to perpetuate the protection by a patent, firms have the opportunity to pay an annual fee for a maximum of 20 years after initial approval. According to the European Patent Convention (EPC 1973, Art. 86), the fee is due annually, beginning with the third year of protection. The respective amount increases over the duration of protection. Even though firms also have to pay for the application of a patent itself, the sum of renewal fees exceed those costs by far (see Figure A9 in Appendix F). Further, if the fee is not paid within the first six months of the due date, the patent is automatically withdrawn and protection terminates.

According to the European Patent Office (EPO 2018) renewal fee payments are a direct indicator for the validity of a patent. More importantly, they indicate patent value: Because of the repeated decision of incurring the costs of annual renewal, only valuable innovations will be renewed multiple times (Schankerman and Pakes 1986).

Notable in the context of this study is that both factors can be directly related to patenting costs. With each year and each jurisdiction the costs of patenting increase. Figure A11 displays the cumulative costs of patenting according to the EPO's fee structure in 2006 which is a relevant year in my sample time frame. The graph comprises application costs, including examination and granting fees. See Gill and Heller (2020), for a detailed description of the European patenting fee schedule.

iii) Invention types:

Regarding the overall direction of an invention, literature commonly differentiates among explorative and incremental (also referred to as exploitative) inventions (e.g. Henderson 1993, Chava *et al.* 2013). Differentiating among these categories is important as it signals the potential to influence future progress. Both types are valuable as they fulfill specific targets. While exploitative inventions are based on successive, minor improvements, explorative inventions involve experimentation with potentially groundbreaking outcomes (Henderson 1993). In my analysis, I consider patent types as being explorative, i.e. having a broad scope and high impact, or incremental. Identification of different patent types cannot be achieved by considering single approximations for each category. Thus, I establish several patent types by defining multiple criteria which a patent needs to fulfill in order to classify for a respective type.

a) Explorative patents: Broad scope and high impact

Scholars highlight the importance of key technologies in driving economic change and growth. In their seminal paper, Bresnahan and Trajtenberg (1995) characterize so-called general purpose technologies by having the potential for pervasive use in several segments of business at the same time. They are associated to foster generalized productivity gains by spreading throughout the economy and triggering spillovers.

Several aspects are required for an invention to be considered as general purpose technology (Bresnahan and Trajtenberg 1995, Rosenberg and Trajtenberg 2004). It should i) exhibit general applicability relevant for the functioning of a broad set of products or processes, ii) have the potential for sustained optimization, and iii) feature a high degree of complementarity, particularly in downstream sectors. The combination of these features suggests a long-lasting impact on productivity and output.

For identifying the degree of generality of a patent, my measurement strategy is closely related to the approach as initially proposed by Trajtenberg *et al.* (1997). Their generality index utilizes information on the distribution of forward citations and International Patent Classification (IPC) technology classes contained in the citing patent documents. In addition to the technological scope, I take into account the degree of the ex post market impact. For these two dimensions (scope and impact), I define several variables as relevant proxies. The scope of a patent can be defined following Lerner (1994) by deriving distinct 4-digit IPC subclasses to which an invention is categorized. To take into account different weights in the distribution across IPC classes, I do not only regard their absolute number but also consider a concentration index, i.e. Herfindahl index of technology classes. The measure ranges between 0 and 1, indicating low (0) or high (1) concentration of IPC classes, respectively. A Herfindahl index equal to one resembles a patent, which relates to only one distinct IPC class. The lower the index, the more IPC classes are relevant.

Further, I use four criteria that classify a patent as a high impact patent. First, I consider the share of claims as a fraction of backward citations. If a patent portfolio has an above average claims ratio, it indicates a high degree of novelty and impact. Second, a patent needs to have received at least one citation (excluding self-citations). Otherwise it arguably does not have a large impact on subsequent inventions. Third, to further specify the impact of a patent the number of citations received has to be higher than the annual average of all citations received by patents in the same industry. Fourth, I consider the share of A-type references which signals the relevance of a reference included in a patent. The most common classifications are X-, Y-, and A-type references. Category X applies whenever a reference taken just by itself would not support that the claimed invention could be considered to involve an inventive step. Similarly, category Y applies, if a document, which is combined with at least one other document, is such that a claimed invention cannot be considered as an inventive step. Category A applies only if a reference is not prejudicial to the novelty or inventive step of the claimed invention. High impact patents should include a high share of these type of references. Hence, I consider a threshold of 80% as a relevant criterion. Overall, three out of these four criteria need to be fulfilled in order for me to classify a patent as having a high impact. Hence, an explorative patent can be expected to exhibit both, a high impact and scope.

b) Incremental patents

Incremental patents have a low degree of exploration and bear only relatively low risk. Notably, these types of inventions can also be of high importance. Progress in general, and specifically inventions can be considered as a cumulative process, and therefore strongly depends on small and steady improvements. As such, incremental inventions may also enhance the efficiency of existing technologies by improving inventions in a step-by-step manner (Ahuja 2000).

To quantify whether a patent can be considered as incremental, I consider four proxies to be relevant which mirror the categories for exploration. First, relative to other inventions, an incremental invention should have fewer claims. A relatively low level of claims symbolizes more narrow boundaries and hence, a more incremental inventive step (OECD 2009). I consider a patent to have relatively few claims, if its claims-to-backward-citation ratio is below the industry-year specific average. Second, the patent should be classified only in one specific IPC4 category resembling a limited scope, which is in line with the exploitation strategy behind incremental inventions. Third, incremental inventions should not receive as much attention as more radical ones. My last proxy is therefore whether a patent did not receive any citations within the first seven years after filing. Fourth, for consistency with the definition on explorative patents, I also consider the share of A-type references in this context. With a sufficiently low share, i.e. 20%, a patent contains mainly references that cannot support the presence of an inventive step. Similar to the criteria on explorative inventions and in order to allow flexibility in the measure, three out of these four criteria should be fulfilled to regard a patent as incremental.

Appendix C:

Empirical mechanism: Two distinct mechanisms induce measurable (*de facto*) improvements in borrowing conditions caused by legal (*de jure*) amendments that foster financial harmonization. First, cross border lending is enhanced due to facilitated movement of capital. Fragmented markets that are based on differences in legal requirements across individual EU member states entail increased risk and information asymmetries which constitute an important impediment for foreign investment (Haliassos and Michaelides 2003). By definition, a relatively more integrated market entails a more similar set of rules as compared to a relatively less integrated market. Aligned regulatory requirements induce reliability and transparency for potential credit suppliers. At the same time it lowers investors' costs of acquiring relevant information (Huberman 2001). If these cost improvements are passed through to borrowers, demand for loans increases eventually alleviating restricted access to financial resources. Haselmann *et al.* (2009) provide evidence that access to bank loans improves for firms domiciled in previously less integrated markets, resulting in increased borrowing activity.

Second, financial integration changes the existing set of rules of all market participants and thus also affects domestic banking activities. Improvements in the legal setup allow a more efficient allocation of capital by reducing frictions in the financial intermediation process which stimulates domestic lending conditions. For instance, Liberti and Mian (2010) argue that decreased collateral costs mitigate borrowing constraints. In addition, market entry of firms resembles an increase in competition due to the removal of (formal) barriers. These changes in the competitive structure of domestic banks improve borrowing conditions (e.g. Chava *et al.* 2013).

Mitigating endogeneity concerns: The specific modeling of the measure (Equation 1) mitigates endogeneity concerns for several reasons. First, the elements of the FSAP in the integration measure, namely EU Directives, can be considered as non-anticipatory. Aside of 28 Directives, the 42 amendments stipulated by the FSAP also encompassed several regulations, recommendations and comments. These other instruments potentially work against the empirical strategy, because they do not result in changes in law (recommendations and comments) or they are strictly binding at a pre-defined and therefore potentially anticipated point in time (regulations). In contrast, EU Directives become effective on an individual country-specific basis after passing domestic legislation. This transposition process is notoriously slow, as it demands for modifications of existing institutional structures, the removal of previous regulations, and oftentimes the renewal of agencies and infrastructure. In practice the implementation of EU Directives usually requires multiple years and varies considerably across member states (Kalemli-Özcan *et al.* 2010, 2013). I take advantage of this circumstance by measuring integration not only as a simple count of implemented directives in a respective country at a certain time, but instead weighting this implementation by the number of other EU members that have also implemented the same directive. Hence, my integration measure will capture the multi-lateral nature of legal harmonization processes on supra-national levels. Moreover, I only regard seven directives related to the banking sector. This is plausible, because I thereby focus on legal changes that have a direct impact on the variable of interest, i.e. external bank finance.

Further, the sequential implementation of the FSAP Directives is unlikely to pick up market responses. The general implementation schedule was set years in advanced by the European Commission. While the transposition windows for implementing each directive is quite narrow, variations in domestic implementations occur due to differences in aforementioned national legislative procedures. Furthermore, the implementation of the directives is unilateral (at domestic level), whereas financial integration is a multilateral concept (Kalemli-Özcan *et al.* 2013). Hence, the FSAP Directives resemble political decisions made years in advanced, so that implementation is unlikely to reflect market responses several years later (Christensen *et al.* 2016).

Moreover, individual firms' actions might be related to specific country initiatives. This could be problematic, as estimations are made on the firm level. However, in my setup implementation decisions are made on a supra-national, European level, which mitigates this concern (Schnabel and Seckinger 2019).

Combining the above suggests that in order for endogeneity to be of a concern, countries would have to experience differentially timed local shocks, each promoting lawmakers to start transposition. These actions would have to be anticipatory in nature and reflect firm-specific issues, which are additionally only relevant for specific firms. Eventually, it appears unlikely that FSAP directives targeted medium termed innovative activities many years in advanced.

Appendix D: Testing DID prerequisites

Descriptive statistics (Table A4 in Appendix E) reveal that exposed firms have on average higher patenting values along most dimensions. A valid DID setup does not require that comparison groups are identical as long as they move in parallel trends. To provide confidence in the empirical approach despite these differences in observable firm characteristics, I test whether ex-ante constrained and unconstrained firms follow a common path regarding the main outcome variables before the treatment unfolds. I follow Angrist and Pischke (2008) by including a time trend variable in a subsample of pre-treatment periods as well as an interaction of this trend with the indicator variable that is equal to one if a firm belongs to the treatment or zero otherwise. The trend variable is a simple year count capturing general anticipatory pre-treatment movements. The coefficient of the interaction term displays whether there are deviating trends between treatment and control groups. Any non-zero effects indicate a violation of the parallel trend assumption. Table A22 (Appendix E) contains the results using patent filings, bank loans, and patent quality variables as dependent variable. The cutoff for the pre-treatment varies is set to $FI_{ct} \leq 0.2$ (with the exception of bank loans, with $FI_{ct} = 0$). Consistent across specifications, coefficients are statistically insignificant suggesting that firms from treatment and control groups move along similar paths.

In addition to this, a graphical analysis investigates potential anticipatory effects in a more detailed way. Here, the pre-treatment period is again set to end for values of $FI_{ct} \leq 0.2$. This allows to construct country-specific year-to-year comparisons for movements during the pre-treatment period. Figure A10 (Appendix F) plots coefficients for indicators that interact the relative-years with the treatment dummy. The coefficients fluctuate over time without a consistent pattern and are not statistically significant. In sum, these analyses cannot invalidate the necessary assumption of parallel pre-trends.

Appendix E: Tables (A1-A22)

Table A1: Sample distribution across sectors (NACE Rev. 2)

Category	**Obs.**	**(in %)**	**Patents**	**(in %)**
A - Agriculture, forestry, and fishing	648	(0.52)	889	(0.13)
B - Mining and quarrying	570	(0.45)	9,371	(1.41)
C - Manufacturing	69,951	(55.83)	428,874	(64.69)
10 - Food products	2,240	(2.54)	5,975	(1.39)
11 - Beverages	271	(0.31)	469	(0.10)
12 - Tobacco products	67	(0.08)	252	(0.06)
13 - Textiles	1,658	(1.88)	2,027	(0.47)
14 - Wearing apparel	545	(0.62)	464	(0.11)
15 - Leather and related products	319	(0.44)	373	(0.09)
16 - Wood products, excluding furniture	1,441	(1.63)	1,254	(0.29)
17 - Paper and paper products	1,723	(1.95)	6,662	(1.55)
18 - Printing and reprod. of rec. media	959	(1.09)	761	(0.18)
19 - Coke and petroleum	172	(0.19)	990	(0.23)
20 - Chemicals and chemical prod.	5,196	(5.89)	54,138	(12.62)
21 - Pharmaceuticals	2,570	(2.91)	37,131	(8.66)
22 - Rubber and plastics	7,003	(7.93)	22,032	(5.14)
23 - Other non-metallic mineral prod.	2,967	(3.36)	8,557	(2.00)
24 - Basic metals	1,643	(1.86)	7,293	(1.70)
25 - Fabricated metals	11,842	(13.41)	23,221	(5.41)
26 - Computer, electronics, optical prod.	9,940	(11.26)	38,622	(9.01)
27 - Electrical equipment	6,342	(7.18)	37,017	(8.63)
28 - Machinery (n.e.c.)	17,383	(19.69)	77,632	(18.10)
29 - Motor vehicles	2,822	(3.20)	58,349	(13.61)
30 - Other transport equipment	1,738	(1.97)	17,602	(4.10)
31 - Furniture	1,439	(1.63)	1,648	(0.38)
32 - Other machinery	6,345	(7.19)	19,946	(4.65)
33 - Repair and install. of machinery	1,578	(1.79)	6,459	(1.51)
D - Electricity and gas	641	(0.51)	1,425	(0.21)
E - Water supply	768	(0.61)	591	(0.09)
F - Construction	4,546	(3.63)	6,645	(1.00)
G - Wholesale and retail trade	17,597	(14.04)	38,407	(5.79)
H - Transportation and storage	1,097	(0.88)	8,323	(1.26)
I - Accommodation	301	(0.24)	111	(0.02)
J - Information and communication	6,065	(4.84)	17,942	(2.71)
L - Real estate	1,125	(0.90)	1,715	(0.26)
M - Professional, scientific, tech. activities	17,485	(13.95)	117,298	(17.69)
N - Administration	3,198	(2.55)	28,779	(4.34)
Q - Human health	778	(0.62)	1,867	(0.28)
R - Arts, entertainment	530	(0.42)	758	(0.11)
Total	125,300	(100.00)	925,989	(100.00)

Notes: The table displays the distribution of observations in the main sample across sectors according to NACE Rev. 2 main categories. In the raw data, all sectors are included but I exclude financial and services sectors (i.e. NACE categories K, O, P, S, T, and U). In addition to the absolute and relative occurrence of observations, the corresponding values for the number of patents filed by sample firms in these sectors are also provided. The shares as fractions of total are indicated in parentheses next to respective values. The percentage (in the bracketes) on the subdivisions of the manufacturing sector (categories 10-33) represent the share of observations within the overall manufacturing sector, respectively patents filed by these firms.

Table A2: Correlation matrix for the patent measures

	Forward citations	Claims	Family size	Renewals	Incremental	Explorative
Fwd. citations	1.0000					
Claims	0.2619	1.0000				
Family size	0.0301	0.1092	1.0000			
Renewals	-0.0528	0.3077	0.0627	1.0000		
Incremental	-0.2128	-0.1583	-0.1489	0.0412	1.0000	
Explorative	0.2666	0.2685	0.0472	0.0210	-0.2425	1.0000

Table A3: List of FSAP Directives

Directive	**Name**	**Transposition date**
2000/46/EC	E-Money Directive*	27/04/2002
2000/64/EC	Dir. on information exchange with 3^{rd} countries	17/11/2002
2001/17/EC	Dir. on the reorganisation and winding up of insurance undertakings	20/04/2003
2001/97/EC	2^{nd} Money Laundering Directive*	15/06/2003
2001/107/EC	UCITS III - Directive (1)	13/08/2003
2001/108/EC	UCITS III - Directive (2)	13/08/2003
2002/83/EC	Solvency Margins Requirements Directive	20/09/2003
2002/13/EC	Solvency 1 Directive for non-life insurance	20/09/2003
2002/83/EC	Solvency 1 Directive for life insurance	20/09/2003
2002/47/EC	Financial Collateral Directive	27/12/2003
2003/48/EC	Savings Tax Directive*	01/01/2004
2001/65/EC	Fair Value Accounting Directive	01/01/2004
2001/24/EC	Directive on the reorganisation and winding up of credit institutions*	05/05/2004
2002/87/EC	Financial Conglomerates Directive*	11/08/2004
2002/65/EC	Distance Marketing Directive	09/10/2004
2001/86/EC	European Company Statute Directive	10/10/2004
2003/6/EC	Market Abuse Directive	12/10/2004
2003/51/EC	Modernisation Directive	01/01/2005
2002/92/EC	Insurance Mediation Directive	15/01/2005
2003/71/EC	Prospectus Directive	30/06/2005
2003/41/EC	Dir. on the activities and supervision of IORP	23/09/2005
2004/25/EC	Takeover Bid Directive	20/05/2006
2006/48/EC	Capital Requirement Directive (1)*	31/12/2006
2006/49/EC	Capital Requirement Directive (2)*	31/12/2006
2004/109/EC	Transparency Directive	21/01/2007
2004/39/EC	Markets in Financial Instruments Dir. (MiFID)	01/11/2007
2005/56/EC	Cross-Border Merger Directive	25/11/2007

Notes: The table lists the 27 FSAP Directives including a short description. Directives market with * are banking-related FSAP measures as identified by Malcolm *et al.* (2009). Transposition dates refer to the intended implementation deadline set by the EU. Actual transposition dates significantly vary between countries. Individual dates are therefore not reported but can be provided by the author upon request.

Table A4: Summary statistics differentiating among treated and control group firms

Variable	Mean		Difference
	Exposed	Control	in means
Panel A: Firm characteristics			
Firm size (log. assets)	7.351	8.801	-1.449***
Tangibility	0.187	0.204	-0.016***
Cash-flow ratio	0.029	0.093	-0.064***
Profitability (RoA)	0.070	0.057	0.013***
Debt ratio	0.646	0.598	0.048***
Bank loan ratio	0.169	0.209	0.040***
Interest rate	0.084	0.069	0.014***
Age	10.662	32.340	21.678***
Quoted (share)	0.046	0.025	0.021***
Panel B: Patent variables			
1) Nr. of patents filed	7.145	2.437	4.708***
2) Forward cits. (7-yr.)	1.949	1.533	0.417***
3) Claims -ratio	0.433	0.381	0.052***
4) Family size	4.063	3.586	0.477***
5) Renewals	9.081	8.864	0.217***
Backward cits.	3.542	3.259	0.284***
Patent scope	0.801	0.822	-0.021***
IPC concentration index	1.753	1.633	0.120***
A-Type reference share	0.158	0.178	-0.021***
Originality-index (8)	0.330	0.317	0.013***
Panel C: Patent types (indicators)			
6) Incremental	0.420	0.449	-0.029***
7) Explorative	0.019	0.015	0.004***
High impact	0.053	0.051	0.002*
Tech. diverse	0.291	0.255	0.036***

Notes: The table displays statistics on firm characteristics (Panel A) and several measures of patenting activities (Panel B and C) similar to Table 3 but differentiates among treated (Exposed) and control (Control) group firms. These categories are based on firms' pre- treatment level of financing constrains as measured by the S&A index (Hadlock and Pierce 2010). The last column contains the differences in mean values, where *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A5: Definition of control variables (firm- and macro-level)

Firm-level controls:	
Firm size	Logarithm of total assets (truncated at 1 percent level)
Tangibility	Fraction of tangible fixed assets over total fixed assets
Cash-flow	Total cash flow as a fraction of total assets (truncated)
Profitability	Return on assets, i.e. EBIT over total assets (truncated)
Macro-level controls:	
Economic conditions	Gross domestic product per capita
Productivity	Labor productivity (output per hours worked)
Financial development	Banking sector Herfindahl-index
Business cycle	ECB financial distress indicator

Notes: The table defines the set of control variables. I calculate firm-level controls based on observable firm characteristics contained in the Amadeus database. To control for outliers, I eliminate outliers by windsorizing variables at the 1 percent level whenever indicated ('*truncated*'). Macro-controls are obtained from the OECD's statistical database (OECD.Stats) and the data warehouse of the European Central Bank.

Table A6: Testing the sensitivity to different variants of patent filings

Dependent variable:	Patent filings (normalized)							
Model:	OLS				PQML			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × Exposure	0.009***	0.012***	0.012***	0.015***	0.063	0.150***	0.140***	0.149***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.045)	(0.028)	(0.028)	(0.029)
FI	0.002	0.002			-0.125**	0.109**		
	(0.003)	(0.003)			(0.059)	(0.048)		
Exposure	0.037***				0.351***			
	(0.002)				(0.004)			
Additional controls:								
Macro-level	Yes	Yes	No	No	No	Yes	No	No
Industry-FE	Yes	No	No	No	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Country-Year-FE	No	No	Yes	Yes	No	No	Yes	Yes
Industry-Year-FE	No	No	No	Yes	No	No	No	Yes
Observations	125,300	125,300	125,300	125,300	79,923	79,923	79,923	79,923

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on the number of firms' annual patent filings and tests the robustness of baseline estimations by using normalized patenting values. PQML estimations use the logarithm of normalized patent filings. Filings are normalized by relating each value to the industry-year-specific maximum value, i.e. $P^{norm.} = filings_{it}/max.filings_{cnt}$ for firm i in country c, industry n, and at time t. Despite the normalization of the dependent variable, all specifications and variable definitions are equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A7: Main specification: financial integration and patent quality measures

Panel A:	Patents' technological quality			
Dependent variables:	Forward citations		Claims	
	(I)	(II)	(III)	(IV)
FI × Exposure	0.066	0.204	-0.068**	-0.025
	(0.117)	(0.138)	(0.031)	(0.038)
FI	-1.162***		-0.336***	
	(0.165)		(0.046)	
Exposure	0.199**		0.107***	
	(0.083)		(0.022)	
Panel B:	Patent value proxies			
Dependent variables:	Family size		Renewals	
	(V)	(VI)	(VII)	(VIII)
FI × Exposure	-0.162*	-0.303***	-0.128***	-0.160***
	(0.088)	(0.105)	(0.038)	(0.052)
FI	-0.507**		-0.173***	
	(0.121)		(0.053)	
Exposure	0.649***		0.077***	
	(0.066)		(0.027)	
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes
Observations	42,401	42,401	42,401	42,401

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on measures of patent quality, i.e. technological quality (Panel A) and market value proxies (Panel B). The quality dimensions are defined in Table 2. Regressions repeat two variants of the main estimations (Table 4), including the baseline specification defined in Equation (2). Despite the use of different dependent variables, all specifications and variable definitions are identical. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A8: Main specification: financial integration and patent types

Patenting dimensions:	Patenting types			
Panel A				
Dependent variables:	Explorative		Incremental	
	(I)	(II)	(III)	(IV)
FI × Exposure	0.000	-0.001	0.017***	0.010
	(0.003)	(0.004)	(0.005)	(0.006)
FI	-0.017***		0.015*	
	(0.004)		(0.008)	
Exposure	0.002		-0.027***	
	(0.002)		(0.004)	
Panel B				
Dependent variables:	High impact		Technological diverse	
	(V)	(VI)	(VII)	(VIII)
FI × Exposure	-0.042***	0.002	-0.023**	-0.024*
	(0.007)	(0.006)	(0.011)	(0.013)
FI	0.002		-0.023	
	(0.003)		(0.015)	
Exposure	0.002		0.034***	
	(0.005)		(0.007)	
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes
Observations	42,401	42,401	42,401	42,401

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on different patent types. Patent types are defined in Table 2. Regressions repeat two variants of the main estimations (Table 4), including the baseline specification defined in Equation (2). Despite the use of different dependent variables, all specifications and variable definitions are identical. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A9: Reestimating main specifications on patent quality measures using PQML

Panel A				
Patenting dimensions:	Technological quality		Market value	
Dependent variables:	Forward citations	Claims	Family size	Renewals
	(I)	(II)	(III)	(IV)
FI × Exposure	0.103	0.017	-0.023	-0.245***
	(0.063)	(0.066)	(0.016)	(0.076)
Panel B				
Patenting dimensions:	Patent types			
Dependent variables:	Explorative	Incremental	High impact	Technological diverse
	(V)	(VI)	(VII)	(VIII)
FI × Exposure	-0.062	0.024**	0.034	-0.107***
	(0.0147)	(0.012)	(0.081)	(0.035)
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Observations	42,401	42,401	42,401	42,401

Notes: This table displays DID estimators from Poisson pseudo quasi-maximum likelihood regressions explaining the effect of financial integration on different patent quality outcomes. Patenting outcomes are defined in Table 2 and used as dependent variables. Specifications follow the same structure as PQML estimations with multiple levels of fixed effects from Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A10: The effect of financial integration on patenting using maximum values

Panel A				
Patenting dimensions:	Technological quality		Market value	
Dependent variables:	Forward citations	Claims	Family size	Renewals
	(I)	(II)	(III)	(IV)
FI × Exposure	-0.086	-0.715	-0.379**	-1.080***
	(0.636)	(0.693)	(0.149)	(0.207)
Panel B				
Patenting dimensions:	Patent types			
Dependent variables:	Explorative	Incremental	High impact	Technological diverse
	(V)	(VI)	(VII)	(VIII)
FI × Exposure	0.033**	0.012	0.020	-0.025
	(0.015)	(0.018)	(0.018)	(0.018)
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Observations	42,401	42,401	42,401	42,401

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on different patent quality outcomes. The dependent variables are the main quality dimensions defined in Table 2. Unlike in the baseline setting, the maximum firm-year values of each patent characteristic are used as dependent variables. Note that these maximum values indicate whether a firm files at least one patent of a certain characteristic. Despite this, all specifications and variable definitions are equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A11: Financial integration, borrowing, and its costs: the degree of constraints

Panel A

Dependent variable:	Bank debt (log.)					
Exposure threshold:	Q50		Q66		Q75	
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × Exposure	0.133***	0.101***	0.170***	0.110***	0.179***	0.114***
	(0.027)	(0.028)	(0.033)	(0.034)	(0.039)	(0.039)
Exposure	-0.039		-0.073**		-0.088**	
	(0.028)		(0.031)		(0.035)	
FI	0.205***		0.221***		0.231**	
	(0.037)		(0.036)		(0.036)	

Panel B

Dependent variable:	Bank loan ratio					
Exposure threshold:	Q50		Q66		Q75	
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × Exposure	0.015***	0.010***	0.023***	0.016***	0.023***	0.016***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Exposure	-0.021***		-0.033***		-0.039***	
	(0.003)		(0.004)		(0.004)	
FI	-0.001		0.000		0.002	
	(0.004)		(0.004)		(0.004)	
Additional controls in both panels:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes	No	Yes
Observations	113,664	113,664	113,664	113,664	113,664	113,664

Notes: This table presents OLS estimates from fixed-effect panel regressions explaining the effect of financial integration on the use of bank loans using different definitions of the exposure variable. The use of bank loans is measured by the logarithm of bank loans (Panel A) and the bank debt to asset ratio (Panel B), respectively. Regressions are repeated with varying definitions on the indicator of whether a firm can be considered as exposed to the treatment (= 1) or not (= 0) according to different cutoff thresholds using the median (Q50) (Column I and II), the 66th percentile (Q66) (Column III and IV), and the 75th percentile (Q75) (Column V and VI). Regressions repeat two variants of the main estimations (Table 4), including the baseline specification defined in Equation (2). Despite the use of different dependent variables, all specifications and variable definitions are identical. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A12: Panel regression results: financial integration and interest burden

Dependent variable:	Interest burden			
	(I)	(II)	(III)	(IV)
FI × Exposure	-0.010***	-0.010***	-0.011***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
FI	-0.019***	-0.016***		
	(0.003)	(0.003)		
Exposure	0.019***			
	(0.002)			
Log. assets	-0.001**	-0.012***	-0.012***	-0.012***
	(0.000)	(0.001)	(0.001)	(0.001)
Tangibility	0.027***	0.033***	0.031***	0.030***
	(0.004)	(0.006)	(0.007)	(0.007)
Cash-flow	-0.047***	-0.039***	-0.037***	-0.036***
	(0.005)	(0.006)	(0.006)	(0.006)
Profitability	-0.005	-0.004	-0.004	-0.004
	(0.005)	(0.006)	(0.006)	(0.006)
Constant	0.080***	0.189***	0.190***	0.194***
	(0.012)	(0.017)	(0.014)	(0.014)
Additional controls:				
Macro-level	Yes	Yes	No	No
Industry-FE	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes
Country-Year-FE	No	No	Yes	Yes
Industry-Year-FE	No	No	No	Yes
Observations	66,168	66,168	66,168	66,168

Notes: This table presents estimates from fixed-effect panel regressions explaining the effect of financial integration on firm-level interest burden in a DID setup. Interest burden is calculated as the sum of all interest expenses in a given period as a fraction of the average debt held during that period. To capture the effect on partial rationing, the sample comprises firms with a positive pre-treatment demand for bank loans. Despite this, all specifications and variable definitions follow the variants used for the main results and are thus equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A13: Reestimating placebo regressions on eurozone countries

	Binary			Continuous		
Panel A:						
Dependent variable:	Patent filings					
Treatment measure:	Binary			Continuous		
	(I)	(II)	(III)	(III)	(IV)	(V)
FI × Exposure	1.485	1.746	1.378	1.253	1.540	0.869
	(1.506)	(1.586)	(1.577)	(1.983)	(2.094)	(2.141)
FI	-1.132	-1.011		-1.827*	-1.743*	
	(0.831)	(0.784)		(1.087)	(0.971)	
Exposure	10.513***			10.952***		
	(1.568)			(1.620)		
Panel B:						
Dependent variable:	Bank debt (log.)					
Treatment measure:	Binary			Continuous		
	(I)	(II)	(III)	(III)	(IV)	(V)
FI × Exposure	0.026	0.002	0.013	0.102**	0.066	0.070
	(0.037)	(0.038)	(0.041)	(0.047)	(0.047)	(0.052)
FI	0.263***	-0.026		0.285***	-0.054	
	(0.037)	(0.038)		(0.069)	(0.078)	
Exposure	-0.035			-0.086*		
	(0.050)			(0.052)		
Additional controls (in Panel A and B):						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	Yes	No	Yes	Yes	No
Industry-FE	Yes	No	No	Yes	No	No
Firm-FE	No	Yes	Yes	No	Yes	Yes
Country-Year-FE	No	No	Yes	No	No	Yes
Obs. (Panel A)	30,376	30,376	30,376	30,376	30,376	30,376
Obs. (Panel B)	29,729	29,729	29,729	29,729	29,729	29,729

Notes: This table presents estimates from panel regressions using an alternative treatment event for explaining the effect of financial integration on firms' annual patent filings (Panel A) and use of bank loans (Panel B) by using a subsample of Eurozone countries. Regressions are specified equivalent to estimations from Tables 8 and 9 with the exception that I exclude all sample countries from the estimations that did not adopt the Euro as an official currency in 1999, such as Denmark, Sweden, and Great Britain. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A14: Placebo estimations across multiple specifications using PQML

Dependent Variable:	Patent filings			
Treatment measure:	Binary		Continuous	
Countries:	All	Eurozone	All	Eurozone
	(I)	(II)	(III)	(IV)
FI × Exposure	0.026 (0.024)	0.046 (0.030)	0.018 (0.025)	0.038 (0.033)
Additional controls:				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Observations	32,335	19,326	32,335	19,326

Notes: This table presents estimates from regressions using an alternative treatment event for explaining the effect of financial integration on firms' annual patent filings. Unlike the main analyses from Table 8, the estimation method is Poisson pseudo quasi-maximum likelihood using the main specification analogue to Equation (2). Estimations are run on the full sample (Columns I and III) and on Eurozone countries only (Columns II and IV). *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A15: Patent quality estimations using the placebo event

Panel A: Technological quality				
Dependent Variable:	Forward Citations		Claims	
Treatment measure:	Binary	Continuous	Binary	Continuous
	(I)	(II)	(III)	(IV)
FI × Exposure	0.082 (0.166)	0.210 (0.245)	0.019 (0.054)	0.111 (0.080)
Panel B: Market value				
Dependent Variable:	Family size		Renewals	
Treatment measure:	Binary	Continuous	Binary	Continuous
	(I)	(II)	(III)	(IV)
FI × Exposure	-0.029 (0.149)	-0.041 (0.208)	-0.097 (0.063)	-0.102 (0.088)
Additional controls (in Panel A and B):				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Observations	10,725	10,725	10,725	10,725

Notes: This table presents estimates from regressions using an alternative treatment event for explaining its effect on quality dimensions of patenting activities. Regressions are repeated with varying definitions on the treatment variable, equivalent to Table 8. All remaining variables are defined as in the baseline specification (**??**) but use the alternative time window between 1997-2005. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A16: Testing firm size as alternative driver for the main results

Dependent Variable:	Patent filings				
Size definitions:	log(employees)	log(assets)	log(salaries)	employee growth	age
	(I)	(II)	(III)	(IV)	(V)
FI × Exposure	2.784**	3.004***	2.810**	3.578***	4.148***
	(1.115)	(1.109)	(1.122)	(1.359)	(1.608)
FI × Size	0.914**	0.784***	1.098***	1.902	0.076*
	(0.432)	(0.276)	(0.378)	(2.018)	(0.041)
Additional controls:					
Firm-level	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	Yes	Yes	Yes	Yes
Industry-FE	Yes	Yes	Yes	Yes	Yes
Var. levels	Yes	Yes	Yes	Yes	Yes
Observations	101,804	125,300	114,314	86,099	124,743

Notes: This table presents estimates from regressions using two interaction terms as main regressors simultaneously. The equations repeat the specification of Column I from the baseline estimates (Table 4). In addition to the DID estimator, here an interaction term of the treatment variable and a size measure is included. The level variables of these interaction terms are included but the estimates are omitted in the output table. Size is defined in five different ways: the log of the total number of employees at the end of the period (Column I), the log of total assets (Column II), the log of total expenditures on employees (Column III), the employee growth rate in a given year (Column IV), and firm age (Column V), respectively. Logically, unlike in the baseline regression these estimations do not additionally control for the logarithm of total assets (with the exception of Column II). *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A17: Financial integration, borrowing, and ex-ante patenting intensity

Dependent variable:	Bank loan ratio			
Ex-ante patenting intensity	High		Low	
	(I)	(II)	(III)	(IV)
FI × Exposure	0.032*	0.041**	0.039**	0.039**
	(0.019)	(0.021)	(0.017)	(0.017)
Exposure	-0.013		-0.028**	
	(0.019)		(0.004)	
FI	-0.001		0.012	
	(0.020)		(0.016)	
(Mean dep. variable)	(0.251)		(0.247)	
Additional controls				
Firm-level	Yes	Yes	Yes	Yes
Macro-level	Yes	No	Yes	No
Industry-FE	Yes	No	Yes	No
Firm-FE	No	Yes	No	Yes
Country-Year-FE	No	Yes	No	Yes
Observations	7,033	7,033	11,268	11,268

Notes: This table presents estimates from fixed-effect panel regressions explaining the effect of financial integration on firms' bank loan ratios distinguishing between firms according to their pre-treatment patenting intensities. Firms are classified as high (low) patenting-intensive if their pre-treatment patenting expenditures are above (below) the sample median during that period. The unweighted mean of the dependent variable for the two subgroups of firms is displayed below the coefficients. An undisplayed t-test shows that the difference in means is statistically not different from zero (with a t-statistics: $t = 0.928$). Regressions repeat two variants of the main estimations (Table 4), including the baseline specification defined in Equation (2). Despite the use of different dependent variables, all specifications and variable definitions are identical. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A18: Heterogeneous treatment effects: the role of ex-ante patenting intensities

Dependent Variable:	Patent filings			
Model:	OLS		PQML	
	(I)	(II)	(III)	(IV)
Panel A: High ex-ante patenting intensity				
FI × Exposure	20.607***	20.267***	0.734***	0.731***
	(7.875)	(7.165)	(0.227)	(0.093)
Exposure	25.009***		0.913***	
	(6.062)		(0.351)	
FI	-7.177		-1.292***	
	(6.588)		(0.383)	
(Mean dep. variable)	(21.548)			
	(I)	(II)	(III)	(IV)
Panel B: Low ex-ante patenting intensity				
FI × Exposure	6.554	5.707	0.446*	0.412***
	(6.219)	(5.637)	(0.261)	(0.101)
Exposure	21.126***		0.684***	
	(4.804)		(0.115)	
FI	-1.507*		0.057	
	(3.379)		(0.434)	
(Mean dep. variable)	(12.863)			
Additional controls in Panel A and B:				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Obs. (Panel A)	7,449	7,449	5,969	5,969
Obs. (Panel B)	11,946	11,946	8,546	8,546

Notes: This table presents estimates from panel regressions explaining the effect of financial integration on the number of firms' annual patent filings. Regressions distinguish between firms with high (Panel A) and low (Panel B) pre-treatment patenting intensities. Firms are classified as high (low) patenting intensive if their pre-treatment patenting expenditures are above (below) the sample median during that period. Below the coefficients, the unweighted means of the dependent variable for the two subgroups of firms are displayed. Regressions repeat two variants of the main estimations (Table 4), including the baseline specification defined in Equation (2), and adapt variable definitions accordingly. Columns I and II use fixed-effect panel regressions, while Columns III and IV repeat those specifications using Poisson pseudo quasi-maximum likelihood (PQML) regression with multiple levels of fixed effects. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A19: Heterogeneous treatment effects: patenting intensity and patent quality

Patenting dimensions:	Technological quality		Market value		Patent types	
Dependent variables:	Forward citations	Claims	Family size	Renewals	Incre-mental	Explo-rative
	(I)	(II)	(III)	(IV)	(V)	(VI)
Panel A: High ex-ante patenting intensity						
FI × Exposure	-0.727*	-0.151	-0.635*	-0.242	0.024	-0.021*
	(0.409)	(0.100)	(0.351)	(0.151)	(0.016)	(0.011)
Panel B: Low ex-ante patenting intensity						
FI × Exposure	0.759**	0.003	0.413	-0.050	0.015	0.013
	(0.361)	(0.081)	(0.275)	(0.089)	(0.016)	(0.009)
Additional controls in Panel A and B:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs. (Panel A)	3,774	3,774	3,774	3,774	3,774	3,774
Obs. (Panel B)	4,607	4,607	4,607	4,607	4,607	4,607

Notes: This table presents estimates from fixed-effect panel regressions explaining the effect of financial integration on different quality dimensions of patented output. Regressions are similar to the baseline estimation defined in Equation (2) but distinguish between firms with high (Panel A) and low (Panel B) pre-treatment patenting intensities. Firms are classified as high (low) patenting intensive if their pre-treatment patenting expenditures are above (below) the sample median during that period. The dependent variables are the main patent quality dimensions defined in Table 2. All specifications and variable definitions are equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A20: Heterogeneous effects: patenting intensity and patent types (max. values)

Dependent variables:	Explorative	Incremental	High impact	Technological diverse
	(I)	(II)	(III)	(IV)
Panel A: High ex-ante patenting intensity				
FI × Exposure	0.000	0.062**	-0.021	-0.094**
	(0.044)	(0.030)	(0.053)	(0.048)
Panel B: Low ex-ante patenting intensity				
FI × Exposure	0.097**	0.022	0.085*	-0.068
	(0.044)	(0.026)	(0.048)	(0.047)
Additional controls in Panel A and B:				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Obs. (Panel A)	3,774	3,774	3,774	3,774
Obs. (Panel B)	4,607	4,607	4,607	4,607

Notes: This table presents estimates from fixed-effect panel regressions explaining the effect of financial integration on different patent types as defined in Table 2. Regressions are similar to the baseline estimation (Table 4) but distinguish between firms with high (Panel A) and low (Panel B) pre-treatment patenting intensities. Unlike in the baseline setting, the maximum firm-year values of each patent characteristic are used as dependent variables. Note that these maximum values indicate whether a firm files at least one patent of a certain characteristic. Despite this, all specifications and variable definitions are equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Table A21: Patent quality: return on investment

Dependent variables:	Technological quality to patenting expenses ratios			
Variable specification	Regular		Normalized	
Quality dimension	Forward cits.	Claims	Forward cits.	Claims
	(I)	(II)	(III)	(IV)
Panel A: High ex-ante patenting intensity				
FI × Exposure	-0.189***	-0.141	-0.018**	-0.006
	(0.072)	(0.095)	(0.007)	(0.007)
Panel B: Low ex-ante patenting intensity				
FI × Exposure	0.190	0.236	0.025	0.025
	(0.450)	(0.636)	(0.037)	(0.038)
Additional controls in Panel A and B:				
Firm-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Obs. (Panel A)	3,467	3,467	3,467	3,467
Obs. (Panel B)	2,038	2,038	2,038	2,038

Notes: This table presents estimates from fixed-effect panel regressions explaining the effect of financial integration on the return on investment in patenting activities. This efficiency measure is calculated by dividing technological quality measures (i.e. forward citations and claims) by the sum of patenting expenditures during the year. In addition to this share (denoted as 'Regular'), a normalized ratio is also used (denoted as 'Normalized'). The ratio is normalized by relating it to the industry-year-specific maximum value. Regressions are similar to the baseline estimation defined in Equation (2) but distinguish between firms with high (Panel A) and low (Panel B) pre-treatment patenting intensities. Despite this, all specifications and variable definitions are equivalent to those used in Table 4. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

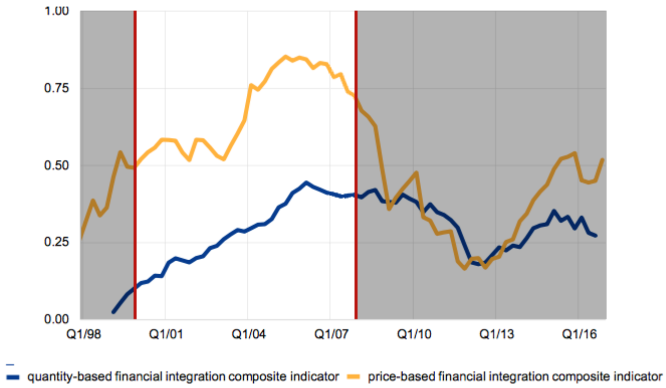
Table A22: Pre-treatment trend regarding different patenting dimensions

Patenting dimensions:			Technological quality		Market value		Patent types	
Dependent variables:	Patent	Bank debt	Forward citations	Claims	Family size	Renewals	Incremental	Explorative
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Exposure × Trend	0.214	0.019	0.077	0.025	-0.068	-0.009	0.004	-0.001
	(0.316)	(0.014)	(0.069)	(0.018)	(0.043)	(0.021)	(0.003)	(0.002)
Trend	-0.200	0.001	-0.042	-0.044	-0.144*	-0.270***	0.005	0.006*
	(0.169)	(0.035)	(0.211)	(0.030)	(0.084)	(0.044)	(0.005)	(0.003)
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	55,177	30,040	19,474	19,474	19,474	19,474	19,474	19,474

Notes: This table presents estimates from regressions explaining different patent quality outcomes and tests for the presence of trends during the pre-treatment period. Pre-treatment is defined as all periods for which the financial integration measure (Equation 1) is 0.2 or lower. The dependent variables are the main patent variables of interest as defined in Table 2. In Column II, the logarithm of bank loans is used as dependent variable. Here the cutoff for the financial integration measures is 0. Regressions contain the same set of control variables as in the baseline regressions but additionally include the following two terms: i) a trend variable which is a running number for each year and ii) an interaction term of the trend variable with the exposure variable indicating whether a firm belongs to the treatment group or not (see Section 3.3). Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

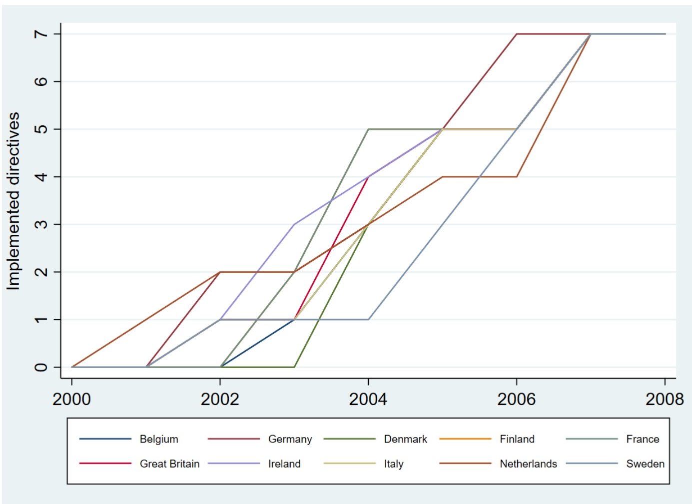
Appendix F : Figures (A1-A10)

Figure A1: Aggregate statistics: ECB financial integration measures



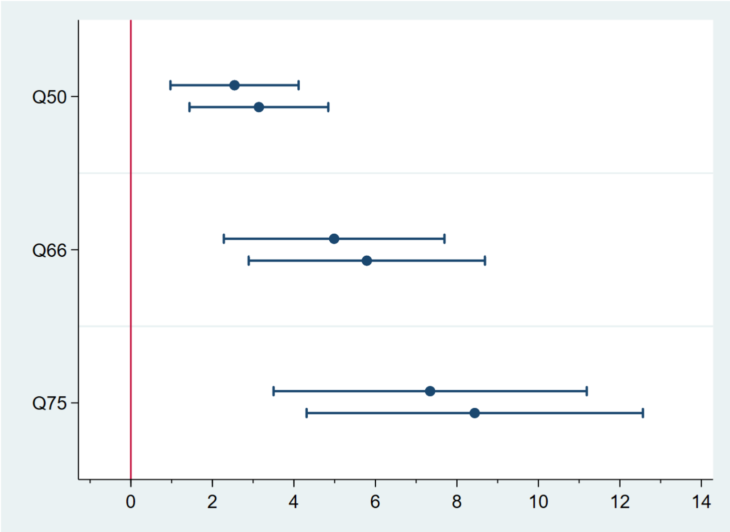
Notes: The figure drafts two measures of financial integration as defined by the European Central Bank (2016) between 1998 and 2016 and highlights the sample time frame (2000-2008). The blue line resembles ECB's quantity-based composite indicator measuring monetary financial institutions' (MFI) loans to non-financial corporations. The yellow line resembles ECB's price-based composite indicator measuring standard deviations of MFI interest rates on new loans to non-financial corporations and households.

Figure A2: Alternative definition of integration measure (non-bilateral dependent)



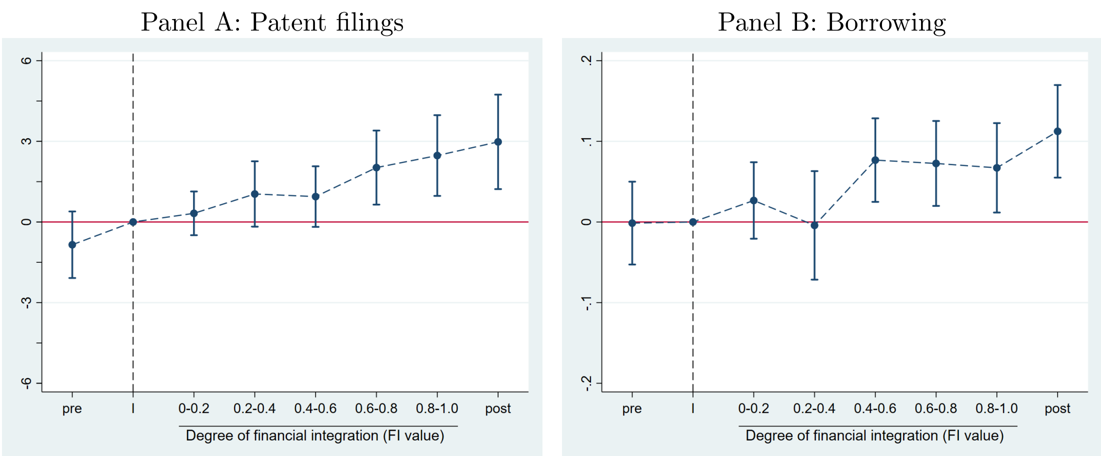
Notes: The figure plots an alternative definition of the integration variable over the sample time frame. Instead of measuring financial integration as defined by Equation (1), this graph regards the absolute number of implemented, banking-related FSAP Directives per country. Here, each color represents one of the countries in the sample. Values of this variable range between 0 and 1, indicating how many Directives are implemented in respective years ranging from zero to seven.

Figure A3: Coefficient plot: Testing different cutoff levels for treatment definition



Notes: This graph plots DID coefficients of baseline regressions (Equation 2) explaining the effect of financial integration on firms' annual number of patent filings. Regressions are repeated using different cutoff values when defining the indicator. A firm can be considered as exposed to the treatment or not with the different cutoffs being the median (Q50), the 66$^{\text{th}}$ percentile (Q66), and the 75$^{\text{th}}$ percentile (Q75). Regressions repeat two variants of the main estimations, i.e. variant one and three in Table 4. Whiskers span the 95 percent confidence intervals.

Figure A4: The lagged impact of financial integration on patent filings and borrowing

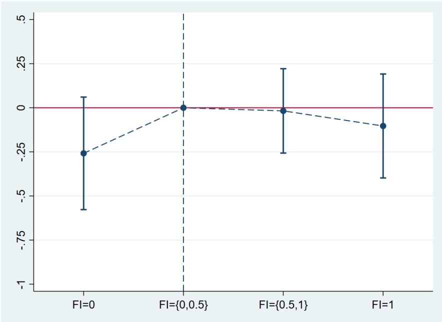


Notes: These coefficient plots graphically illustrate the timing of the impact of financial integration on patenting (Panel A) and borrowing activities (Panel B). Specifically, coefficients of the interaction terms from the event study design regressions specified in Equation (4.3) are displayed using patent filings and the logarithm of bank debt as dependent variables. The process of financial integration is split into five periods defined according to equally-sized bins (i.e. quintiles) of the financial integration measure (Equation 1). The reference time period is the last country-specific year in which $FI_{ct} = 0$. Pre- and post integration periods refer to years in which $FI_{ct} = 0$ (excluding reference period years) and $FI_{ct} = 1$, respectively. Whiskers span the 95 percent confidence intervals.

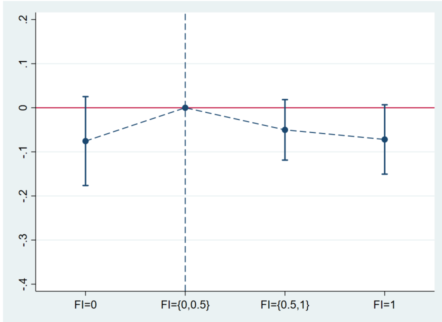
Figure A5: The impact of *de facto* financial integration on patent quality

Panel A: Patent quality

Forward citations:

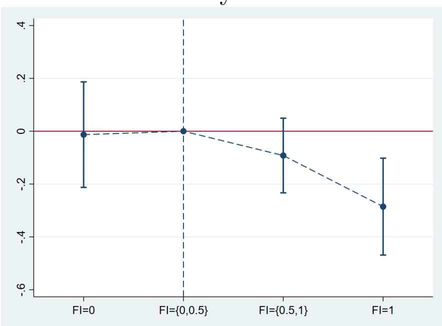


Claims:

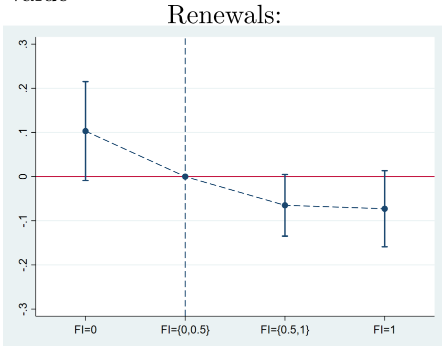


Panel B: Patent value

Family size:

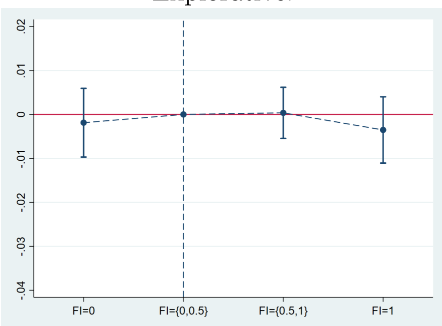


Renewals:

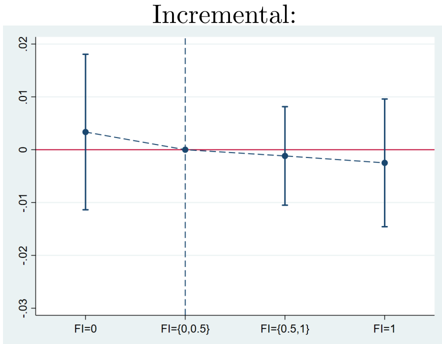


Panel C: Patent types

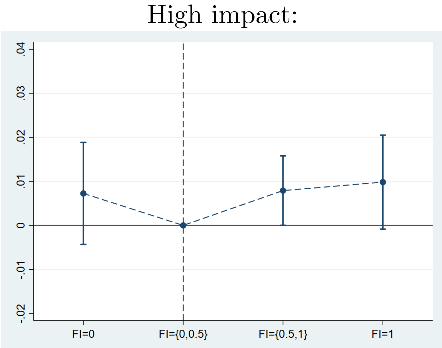
Explorative:



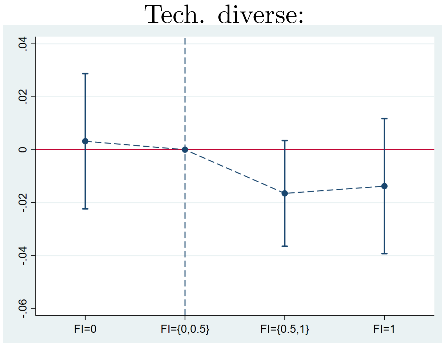
Incremental:



High impact:



Tech. diverse:

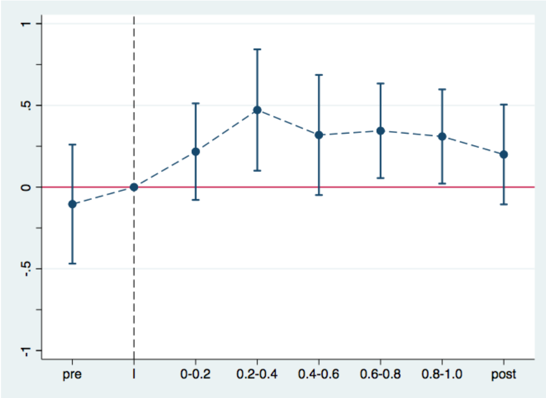


Notes: These graphs illustrates the timing of the impact of financial market integration on borrowing and patenting activities by plotting DID coefficients using different stages of the integration process as interaction. The underlying regressions build on the main specification from Equation (2) but distinguish among four periods of integration: pre-treatment, low integration, high integration, and post treatment. Low (high) integration years are all country-specific observations with $FI < 0.5$ ($FI > 0.5$) except of the years in which $FI = 0$ ($FI = 1$) which are the pre- (post-)treatment periods. The low integration period is used as reference period. Different patent quality and type variables as defined in Table 2 are defined as dependent variable. Respective variables are denoted on top of each chart. Whiskers span the 95 percent confidence intervals.

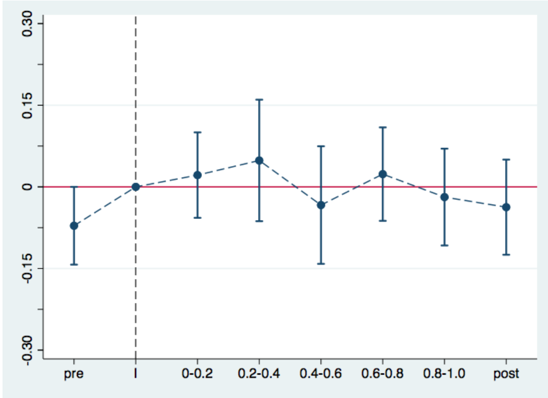
Figure A6: The impact of financial integration on patent quality over time

Panel A: Technological quality

Forward citations:

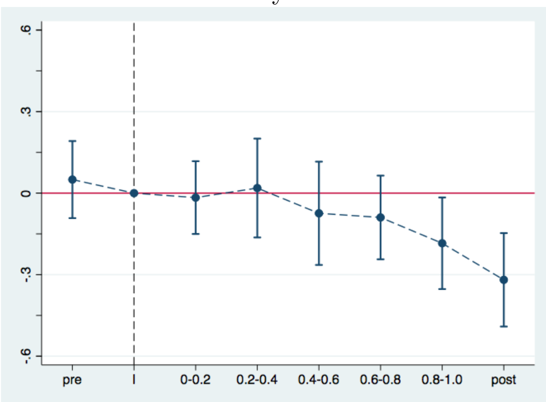


Claims:

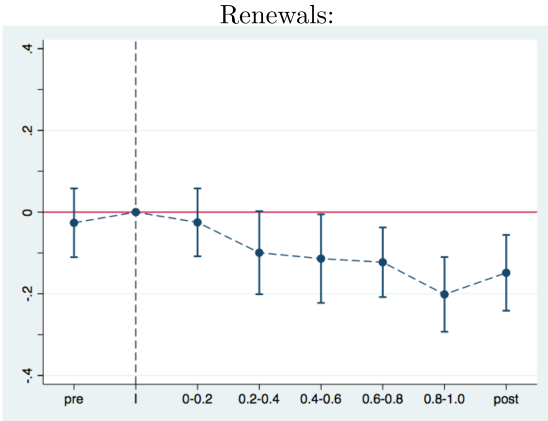


Panel B: Patent value proxies

Family size:

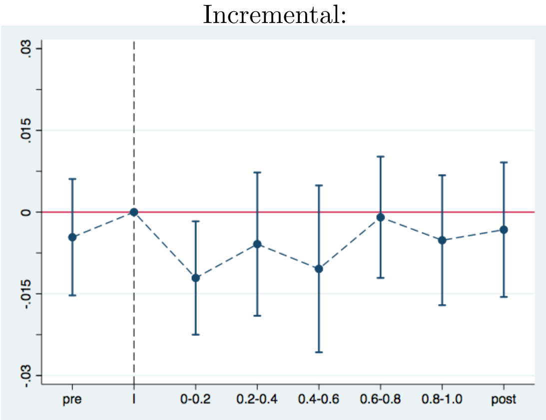


Renewals:

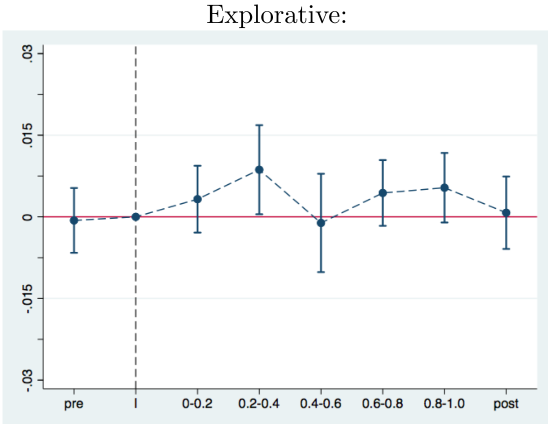


Panel C: Patent types

Incremental:

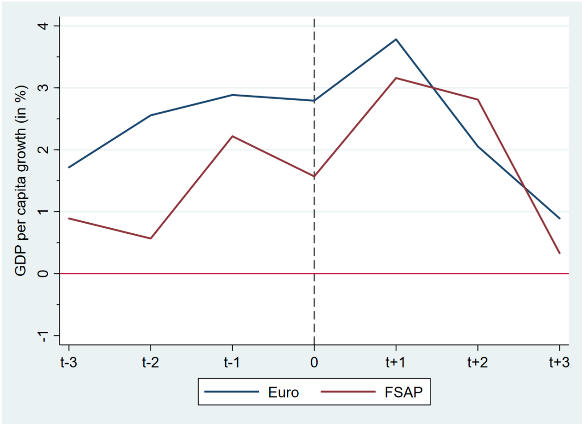


Explorative:



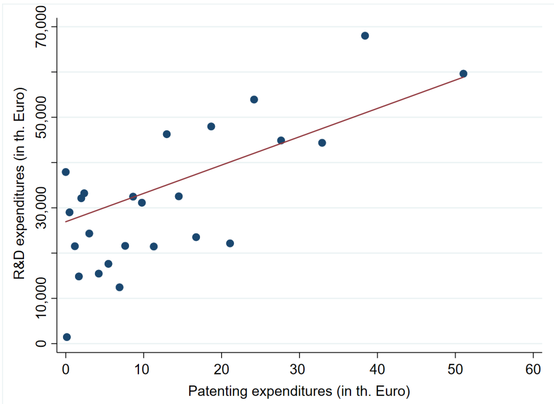
Notes: These coefficient plots graphically illustrate the timing of the impact of financial integration on different patent quality measures, namely their technological quality (Panel A), market value (Panel B), and the share of certain types of patents (Panel C). Specifically, coefficients of the interaction terms from the event study design regressions specified in Equation (4.3) are estimated using the six patent quality variables defined in Table 2 as dependent variable. Respective variables are denoted on top of each chart. The process of financial integration is split into five periods defined according to equally-sized bins (i.e. quintiles) of the financial integration measure (Equation 1). The reference time period is the last country-specific year in which $FI_{ct} = 0$. Pre- and post integration periods refer to years in which $FI_{ct} = 0$ (excluding reference period years) and $FI_{ct} = 1$, respectively. Whiskers span the 95 percent confidence intervals.

Figure A7: Comparing GDP growth rates around the two event windows



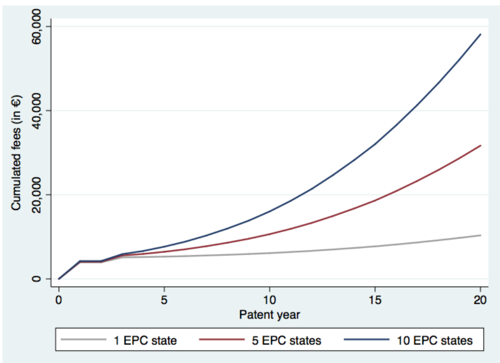
Notes: This graph illustrate the macroeconomic conditions during both the original event window and the placebo event window. On the horizontal axis the years relative to the treatment (t) are denoted. For the original event, this is when the unweighted cross-country average (de jure) financial integration score defined in Equation (1) is larger that 0.5. For the placebo event, t is the year 1999, i.e. the year in which the Euro was introduced as official currency among Eurozone countries. The lines plot the GDP per capita growth rates of the European Union during respective years, both for the original (FSAP) and the placebo event (Euro).

Figure A8: The relationship between R&D- and patenting expenditures



Notes: This binned scatterplot graphically displays the relationship between expenditures on research and development (y-axis) and patenting expenditures (x-axis) of sample firms. The number of bins is set to 25.

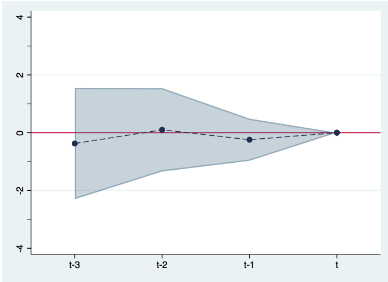
Figure A9: Cumulative patent renewal costs (at multiple patent offices)



Notes: The graph displays the cost structure of patents active in member states of the European Patent Convention (EPC) for any given year subsequent to patent filing ($t = 0$). This includes average annual fees necessary to maintain patent protection for each of the maximum 20 years of patent life. The lines refer to the number of jurisdictions where the patent is maintained, i.e. 1, 5, or 10 jurisdictions. Costs include the most common application, grant, and renewal fees. For illustration purposes we consider the average renewal fees per EPC country based on the payment schedule of 2006 (see Gill and Heller 2020). Costs may actually vary depending on which specific jurisdictions are chosen.

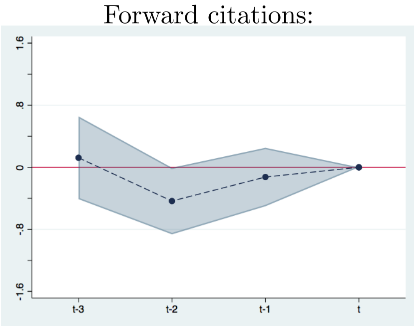
Figure A10: Anticipatory effects on patenting dimensions

Panel A: Patent quantity



Panel B: Technological quality

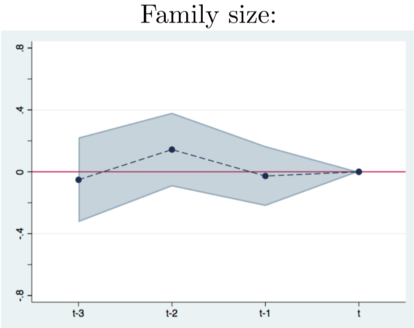
Forward citations:



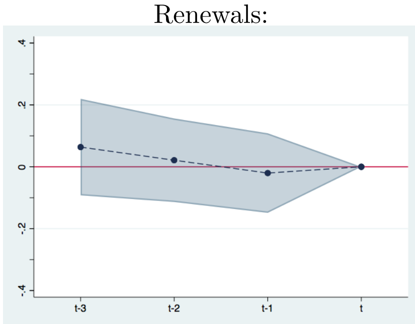
Claims:

Panel C: Patent value proxies

Family size:

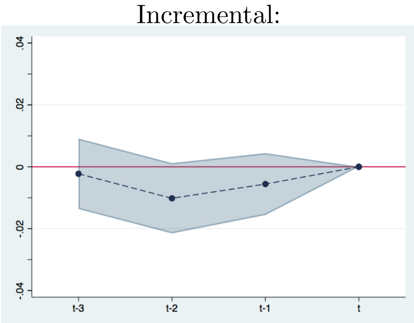


Renewals:

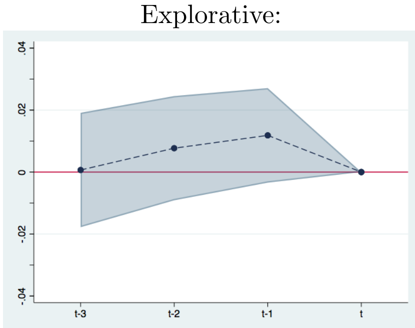


Panel D: Patent types

Incremental:



Explorative:



Notes: These figures display potential deviating trends between treated and control group firms by plotting coefficients of the interaction terms of year- and exposure dummy variables. Year dummies resemble the country-specific years before the treatment is initiated, i.e. $FI \leq 0.2$. Exposure dummies indicate whether a firm is treated or not, i.e. whether it is considered as ex-ante financially constrained. The regressions follow the main specification regarding the selected model and variable definitions (see e.g. Equation 2). The fixed-effect panel regressions are repeated using the seven main patenting variables defined in Table 2 as dependent variable. Respective variables are denoted on top of each chart. Post treatment years are excluded and the reference year (t) marks the country-specific period for which $FI > 0.2$. The shaded area represents the 95 percent confidence intervals of the estimates.