Financial Market Integration and the Effects of Financing Constraints on Innovation*

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This paper investigates the effects of financial market integration on firm-level external debt financing and subsequent inventive activities. To this end, I exploit the implementation of the Financial Services Action Plan (FSAP) as a positive exogenous shift integrating European banking markets during the 2000s. My findings show that higher integration relaxes financing constraints, with significant positive effects on firms' use of debt and interest burden, particularly for ex-ante financially constrained firms. Moreover, financial integration spurs innovative activities in terms of patenting of those firms that benefited from the reforms. Considering a variety of qualitative dimensions shows that lifting financing constraints improves patent *quality* for a subset of previously constrained firms with low ex-ante patenting intensities (entrants) while adversely affecting the inventive output of incumbent patenters in the spirit of a quantity-quality tradeoff. These findings highlight the key function of a conducive financing environment for inventive activities but also reveal unintended limitations of policy-induced improvements in access to financing.

JEL Classification: D04; F36; G32; O3

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- This paper investigates the effects of a major policy reform on financial market integration in Europe, the Financial Services Action Plan (FSAP), on firms' financing and innovative activities.
- The FSAP significantly relaxed financing constraints and improved access to debt financing: Ex-ante constrained firms disproportionally raised more debt and benefited from lower interest burden.
- The increased use of debt translates to increased patent filing activities of respective firms, with significant positive effects on the quantity of patents and neutral effects on the quality.
- Higher levels of patenting are accompanied with declining patent quality for constrained firms with high ex-ante patenting intensities (incumbents), while constrained firms with low intensities (entrants) also produced more high-quality patents.

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1 Introduction

Adequate access to financial resources is pivotal for generating, commercializing, and disseminating inventions (Hall and Lerner 2010; Hottenrott and Peters 2012; Hall *et al.* 2016; Nanda and Rhodes-Kropf 2017). Worldwide, debt financing remains the most common source of external financing and is particularly relevant for relatively small and innovative firms (Berger and Udell 2006; Robb and Robinson 2014; Kerr and Nanda 2015; European Investment Bank 2022). Consistently, public policies are a favorable tool to stimulate firms' access to debt financing, e.g., through enhancing banking market integration (Haselmann *et al.* 2009). However, the (unintended) implications of such policies on inventive activities are unclear a priori. While better access to financing is associated with higher R&D expenditures and patent filings (Brown *et al.* 2009; Aghion *et al.* 2010; Chava *et al.* 2013), several studies find that financial constraints can act as a disciplining device stimulating the innovative efficiency of individuals and firms (Manso 2011; Aghion *et al.* 2013; Almeida *et al.* 2021).[1]

Against this background, this paper is the first to analyze the effects of a significant financial market integration effort, the Financial Services Action Plan (FSAP), on firms' debt financing and patenting activities. The FSAP encompasses major legislative amendments geared towards a more integrated financial market in the European Union (EU). I draw on all bank-related FSAP amendments stipulated by the European Commission as a traceable, exogenous source of variation in the legal environment that improved firms' bank financing conditions across EU member states during the early 2000s. In this context, I assess how banking integration affects firms' use of debt and how this translates to subsequent innovative activities for firms affected by the changes in the financing environment. To do so, I utilize a large-scale sample that includes about 22,000 primarily small and medium-sized firms from eight European countries and data on more than 700,000 patent applications. Further, I measure the quantity and quality of patent output as inventive activities. Taking these two complementary dimensions into account is crucial because both are relevant for long-term value creation and, thus, the economic success of firms (Harhoff and Wagner 2009; de Rassenfosse 2013). Moreover, analyzing patent quality allows for assessing potential disciplining effects of financing constraints on innovative activities, as it acknowledges that increased patenting activities do not necessarily imply more or better innovation, i.e., the patent paradox (Hall and Ziedonis 2001).

I estimate the effects of financial integration in the banking sector on debt financing and innovative activities by exploiting additional cross-sectional variation arising from firms' ex-ante degree of financing constraints. Specifically, I compare ex-ante constrained and unconstrained

[1] Of course, fewer resources cannot lead to ever more or better inventions such that the efficiency effects of financing constraints must be limited. Still, anecdotal and empirical evidence finds a financing-induced quantity-quality tradeoff in patenting activities. In 2018, the British Patent Office announced a substantial increase in patenting fees, aiming to "*encourage good filing practices by applicants*" (UKIPO 2018). Empirical evidence echoes this as higher application fees reduce the number of patent filings but predominantly crowd out low-quality applications, thus enhancing average patent quality (Eaton *et al.* 2004; de Rassenfosse and Jaffe 2018).

firms throughout the adoption period of the FSAP in the spirit of a generalized difference-in-difference (DID) setting with dynamic treatment and multiple fixed effects. The key idea is that changes in financing conditions do not have a uniform impact since firms with an unfulfilled demand for external debt are particularly responsive to changes in the supply of credit (Holmström and Tirole 1997; Duchin *et al.* 2010; Garicano and Steinwender 2016), such as small private firms (Berger and Udell 2006; Brown *et al.* 2009; Becker and Ivashina 2014). The main specifications therefore distinguish firms that are more or less financially constrained using the S&A index proposed by Hadlock and Pierce (2010), which is a function of firm size and age. In alternative specifications, I leverage an industry-level measure of dependence on external debt financing and deploying matched-sample regressions to further mitigate concerns that differences in firm characteristics confound the main results.

The analyses show that the FSAP stimulated firms' financing and patenting activities. The average use of debt increases by about 12%, and the average interest charge decreases by about 6%, comparing pre- and post-integration levels of ex-ante financially constrained firms relative to less constrained firms. Further, moving the average ex-ante constrained firm from the pre- to post-integration period results in a 25% higher likelihood of filing a patent relative to unconstrained firms. The increase in patent filings unfolds over time and follows the increased use of debt financing. Analyzing the qualitative patenting dimensions provides only weak evidence that the FSAP affected the average patent quality, market value, and type of ex-ante constrained firms' patents. In other words, the baseline results indicate that firms generated more patents of relatively similar quality. Hence, these findings suggest a beneficial effect of the legal amendments by relaxing financing constraints.

Through a series of analyses, I emphasize the validity of the main result and the empirical strategy. First, the baseline estimates are robust to a host of additional tests, such as using a variety of alternative definitions of the key variables, model specifications, and other validation tests (e.g., showing that ex-ante constrained and unconstrained firms followed a parallel path in the years prior to the FSAP). Second, I extended the paper's contribution by introducing a price-based integration measure that captures the actual (*de facto*) level of financial integration in the EU. Estimates on the de facto measure are qualitatively similar to the baseline estimates. Third, event study analyses support the empirical strategy by showing a sequential impact on financing and patenting activities and further suggest that (*de jure*) changes in the legal framework require some time to unfold. Fourth, exploring different layers of firm-specific heterogeneity confirms that the main effects are not biased by firms' lifecycle and growth patterns or regional dynamics. Plausibly, I also find that effects are strongest for firms that are more dependent on external financing. Fifth, the results are robust to a placebo test that exploits the introduction of the Euro in 1999 as an alternative treatment event, mitigating concerns that general economic conditions drive the results. The Euro introduction is well-suited for such and analysis as the macroeconomic conditions are comparable to those in the original setting and it constitutes a landmark of EU financial market integration, which, notably, did not significantly affect debt financing conditions (Baele *et al.* 2004). Sixth, I find that additional funding induces firms to raise their patenting intensity in terms of patenting investments measured relative to other operating expenses or capital investments. The increase in patenting expenditures is proportional to the increase in debt financing, which indicates that the additional debt can cover the increased investment in patenting. Finally, further analyses repeat the main specifications but determine firms' responsiveness to the FSAP based on out-of-sample industry-level data. In this setup, I also deploy a matching procedure that removes observable differences across the comparison groups. Again, the results are comparable to the baseline specifications, which significantly reduces endogeneity concerns.

Furthermore, I address methodological concerns regarding the generalized DID estimations in detail. Such settings have fueled a rich debate in econometrics literature, particularly regarding two-way fixed effects DID estimations with staggered treatments (Baker *et al.* 2022; Roth *et al.* 2023). As I show, financial market integration in Europe during the mid-2000s can best be described as a dynamic treatment and, thus, recognizes recent advances in econometrics that emphasize the conceptual and practical benefits of such a setting (De Chaisemartin and d'Haultfoeuille 2020; Sun and Abraham 2021). I take an additional precaution by implementing a set of state-of-the-art validity tests on DID setups with multiple treatments across time, as suggested by Baker *et al.* (2022), which unanimously confirm the previous results.

After having established the broad implications of the FSAP on firms' debt financing and patenting activities, I move one step further and investigate the potential quantity-quality trade-off in greater depth. The baseline results provide an ambiguous picture of the patent quality-related outcomes. Intuitively, such average effects may hide meaningful heterogeneous responses that are eventually helpful in explaining the mechanisms behind the role of financing constraints for firms' patenting activities. Therefore, I repeat the main estimations but distinguish firms with high or low pre-FSAP patenting intensities, which is similar to comparing incumbent patentees with entering firms. These analyses show that both types of firms increase the number of patents filed in response to the FSAP, conditional on being ex-ante financially constrained, i.e., having benefited from the FSAP by improved access to debt financing. However, the effects on patent quality are diverging. Previously constrained firms with *high* ex-ante patenting intensities tend to file more incremental and technologically narrower patents, consistent with relaxing the disciplining effect of financial constraints. In contrast, for previously constrained firms with *low* ex-ante patenting intensities, mitigating financial constraints yields more patents and patents of significantly higher quality. This favorable outcome may be due to a credit-supply effect, which acknowledges the importance of adequate financing for innovative activities. Overall, these results are important as they provide empirical evidence of the positive effects of policy-induced reductions of financing constraints as well as their potential (unintended) adverse implications.

Taken together, the findings enhance our understanding of how improvements in the legal system that aim to stimulate access to finance can affect inventive activities. Such insights are essential for designing effective policies both on the governmental and firm level. Mitigating financing constraints is an often favored target by policymakers and businesses in their attempt to spur firm-level innovation (Hottenrott and Peters 2012; Howell 2017; Audretsch *et al.* 2020; Chiappini *et al.* 2022). Hence, the analyses provide valuable insights into the consequences and potential mechanisms of policy-led adjustments to firms' access to external financing for inventive activities.

This paper adds new evidence to the literature on finance as a key input factor of innovation. The supply of financing drives investments into inventive activities and, therefore, determines the generation, initial commercialization, and diffusion of innovation, particularly in the case of research-intensive firms (Hall and Lerner 2010; Hottenrott and Peters 2012; Hall *et al.* 2016; Nanda and Rhodes-Kropf 2017). A common conclusion is that alleviating financing constraints increases innovative output by inducing firms to invest more in research and development (e.g., Brown *et al.* 2009, Chava *et al.* 2013). Important in this context are recent findings, which emphasize the relevance of external debt financing for inventive activities (Kerr and Nanda 2015; Gill and Heller 2022), particularly the critical role of banks, even for young startups (Robb and Robinson 2014; Saidi and Žaldokas 2021; Hochberg *et al.* 2018; Hirsch and Walz 2019). This study provides important new findings on the role of debt financing for inventive activities in a novel empirical setting, disclosing insights on a significant change in firms' legal environment that exogenously improved their access to debt financing.

Moreover, this paper contributes to the literature on the real economic effects of policy-led financial market development (e.g., La Porta *et al.* 1998; Bertrand *et al.* 2007; Kerr and Nanda 2009). For example, a group of studies investigates US banking deregulation and shows that it increases the sensitivity of bank-lending decisions to firm performance, improves access to debt financing, and fosters inventive activities (Stiroh and Strahan 2003; Chava *et al.* 2013; Amore *et al.* 2013; Cornaggia *et al.* 2015). Unlike these studies, this paper focuses on financial market integration – a different form of market development that improves firms' access to debt financing. Prior literature on financial market integration shows that more integrated markets have fewer entry barriers, better access to finance, and lower interest rate spreads relative to less integrated markets, particularly for small firms (Cetorelli and Strahan 2006; Haselmann *et al.* 2009; Liberti and Mian 2010). Consistent with these studies, my findings underscore the positive effects of banking market integration on debt financing. Importantly, I go beyond related research by examining the subsequent implications on the patenting activities of affected firms, including a broad set of patent quality measures. Furthermore, by examining both de jure and de facto measures of integration, this paper augments the existing analyses by linking legal changes to actual changes in the marketplace; this facet has been largely overlooked in comparable analyses. Hence, this study draws a comprehensive picture of how financial integration shapes inventive activities by assessing the impact of the FSAP on the banking sector, firms' debt financing, and subsequent real economic activities. The results deliver valuable insights regarding the potentials and limitations of policies that focus on monetary input to support innovation and growth.

The paper proceeds as follows. Section 2 outlines the institutional setting and derives potential implications of the FSAP for debt financing and patenting. Section 3 describes the data and patenting dimensions. Section 4 outlines the empirical strategy and provides estimates on the baseline specifications and robustness tests. Section 5 presents further results that elicit the underlying mechanisms. Section 6 concludes.

2 Institutional framework

2.1 Financial integration in Europe: The FSAP

The European Commission officially issued the Financial Services Action Plan (FSAP) in 1999. The prime objective was to integrate financial markets within the EU by harmonizing the regulatory framework. Financial market integration refers to the degree to which comparable market participants face equal market access, the same set of rules, and equal treatment, regardless of their specific geographical location (e.g., Baele *et al.*, 2004). Accordingly, the Commission developed the FSAP along four main goals: the creation of a single EU wholesale market, open and secure retail banking and insurance markets, state-of-the-art prudential rules and supervision, and advancing towards an optimal single financial market. It asked EU member states to implement 42 legislative proposals over six years. These legal changes encompassed two regulations and 27 directives, including seven directives that directly affected the banking sector (Malcolm *et al.* 2009). Table A1 (Appendix A) displays all FSAP Directives and the anticipated implementation timeline of the banking-related directives.

The changes in law stipulated by the FSAP triggered a surge in European banking integration throughout the 2000s. Before the FSAP in the late 1990s, European markets were highly fragmented despite prior integration efforts (e.g., Adam *et al.* 2002; Cabral *et al.* 2002; Grossman and Leblond 2011). The FSAP was important as it substantially raised financial market integration: It induced reliability and transparency in the market, providing confidence in the regulation itself as it represented a change in EU strategy away from market opening measures and towards a more level playing field (Malcolm *et al.* 2009; Quaglia 2010; Meier 2019). More specifically, the amendments enhanced business cycle synchronization and fostered financial development in the banking sector (Kalemli-Özcan *et al.* 2013; Ozkok 2016). Consistent with these insights, aggregate statistics confirm a rise in Eurpean financial market integration for quantity- and price-based integration indicators during the mid-2000s (see Figure A1, Appendix A).

Financial integration and debt financing: The FSAP had specific effects on debt financing, which I explore in this study. As this paper investigates how financial integration affects firms' innovative activities via the bank financing channel, the empirical strategy follows related literature and considers the seven banking-related FSAP Directives (e.g., Kalemli-Özcan *et al.* 2010, 2013). These amendments constituted a major modernization of the legal framework which improved debt financing conditions for firms along several dimensions. It allowed a more efficient allocation of capital by reducing frictions in the financial intermediation process. More integrated markets offer a more similar set of rules than relatively less integrated ones, which eventually mitigates risk and information asymmetries. Such an alignment reduces the costs of lenders to acquire relevant information or monitor debtors (Huberman 2001). Once lenders pass through these cost reductions to borrowers, the prices of loans decrease, and thus, borrowing becomes more affordable for firms, increasing their demand for debt. Relatedly, legal amendments that remove (formal) barriers spur market entry, which increases competition among banks. Such policy-induced changes in the competitive structure of domestic banks are found to improve firms' borrowing conditions (e.g., Cornaggia *et al.* 2015).

These aspects illustrate that financial market integration can enhance access to debt financing and put downward pressure on the cost of debt. Indeed, prior research supports this notion. For example, Liberti and Mian (2010) argue that improved transparency and reliability in the legal framework yields lower collateral costs and thus mitigates borrowing constraints. In a similar vein, Haselmann *et al.* (2009) show that access to bank loans improves for firms domiciled in previously less integrated markets, resulting in increased borrowing activity. Notably, these effects are most pronounced in the presence of financial constraints, e.g., for relatively small and young firms (Cetorelli and Strahan 2006; Brown *et al.* 2009). As one specific example, the so-called Capital Requirements Directives allowed banks to reduce their regulatory capital requirements for claims on SMEs for a given level of risk. These changes directly improved small firms' access to bank funding (see, e.g., Aubier 2007). My analysis builds on these aspects and exploits heterogeneous responses to the increase in banking integration caused by the FSAP.

Financing constraints, debt financing, and patenting: Furthermore, financial integration and especially the resulting improvements in access to debt financing are likely to have subsequent effects on firms' patenting activities. As an underlying mechanism, prior literature points out the "credit-supply" effect as a situation in which increased credit availability triggers innovative activities (e.g., Amore *et al.* 2013; Cornaggia *et al.* 2015; Cerqueiro *et al.* 2017). The intuition is that reducing financing constraints (i.e., a positive shock to the supply of external financing) enables firms to pursue costly innovative activities that were previously stifled. This mechanism builds on research in financial economics that describes the implications of credit supply shocks on firm-level investments (Holmström and Tirole 1997; Duchin *et al.* 2010).

These effects are particularly severe in the presence of financing constraints and for longer-termed investments, such as investments into innovative projects (Garicano and Steinwender 2016). Insufficient financial resources may induce firms to lower investments into research and development even if it implies that they forgo positive net present value projects (Hottenrott and Peters 2012). Reducing the costs of debt and improving access to debt financing relaxes respective firms' financing constraints and should therefore promote their innovative activities, implying a positive relationship between credit availability and innovative activities.

Notwithstanding, the positive effect of relaxing financing constraints on innovative output is not uncontested, especially when considering the qualitative characteristics of innovations. In general, input resource constraints can lead to more efficient use of the existing resources, whereas removing these constraints may trigger wasteful investments (Goldenberg *et al.* 2001; Hoegl *et al.* 2008; Aghion *et al.* 2013). Similarly, tolerance for failure is a strong determinant of innovation incentives and may ultimately induce managers with large research and development (R&D) budgets to conduct more risky, high-profile projects (Manso 2011). In such situations, financial constraints can have a "disciplining" effect that eventually raises innovative efficiency (Almeida *et al.* 2021). As such, more risky projects may not only yield more value, i.e., higher patent quality, but they are also more likely to fail (Nanda and Rhodes-Kropf 2017). In the patenting context, literature mirrors these findings by showing that lowering patenting costs induces firms to file more patents, which may come at the expense of lower patent quality (e.g., Hall and Ziedonis 2001; de Rassenfosse and Jaffe 2018).

Given these contrasting findings, examining the effects of a policy-led decrease in financing constraints on firms' innovative output is an empirical task implemented in this paper. To carry out this analysis, the focus of the empirical setting on financial integration, debt financing, and small and medium-sized, innovation-oriented firms is beneficial for several reasons. First, the FSAP was a major policy shift with real implications on the de facto integration of the European banking sector, constituting a significant improvement in firms' debt financing environment. Second, it is established that debt is an important financing source for innovative firms across a broad range of industries (e.g., Kerr and Nanda 2015). Third, small and financially constrained firms are particularly responsive to changes in the market environment that affect credit availability (Holmström and Tirole 1997; Cetorelli and Strahan 2006; Garicano and Steinwender 2016). For example, small firms are much more limited in their access to financing than larger firms, making them more reliant on external debt as their predominant mode of financing (e.g., Berger and Udell 2006; Robb and Robinson 2014; European Investment Bank 2022). Similarly, small innovative firms' high degree of informational opacity is associated with increased costs of external debt financing, leaving these firms particularly vulnerable to financing conditions (e.g., Hall and Lerner 2010; Becker and Ivashina 2014).[2]

[2] Moreover, due to the high information costs, the financing of innovative firms is particularly volatile, such

2.2 Quantifying financial integration

De jure measure of financial integration: This section first presents the main approach to quantifying financial market integration that is based on the actual legal amendments stipulated by the FSAP. This *de jure* measure of financial integration leverages manually collected data on the effective country-specific transposition dates of all seven banking-related FSAP Directives. The objective is to weigh the implemented directives by the number of other EU members that have also implemented the same directives instead of merely counting the implemented directives over time. This way, the integration measure captures the multi-lateral nature of the legal harmonization processes, similar to prior work on financial integration (e.g., Kalemli-Özcan *et al.* 2013). The de jure integration measure is thus defined as:

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

where D_{dtc} and D_{dtj} (for all $d \in [1,7]$) are equal to one if one of the seven banking-related FSAP Directives is active during the year t (for all $t \in [1999, 2008]$) in country c, or country j (with $c \neq j$) respectively, and zero otherwise. Integration equals the product of these indicator variables for the observed country c and the fraction of all other EU-15 members j in which the respective directive is active. The FI-measure ranges between zero and one, resembling low and high levels of financial market integration, respectively.

This calculation approach mirrors the multilateral concept of integration, and it reflects that integration cannot be unilaterally achieved but requires legislative changes that harmonize the available rules across countries. To illustrate: In a hypothetical scenario with three countries [A, B, C], no integration would be achieved if country A implements all FSAP Directives but countries B and C do not implement any directives. If countries A and B adopt all directives, but C does not, $FI = 0.5$ for countries A and B and 0 for country C. The FI-measure equals 1 only if all countries have implemented all directives at a given time.

Its mutual-dependence yields a realistic integration measure that exhibits substantial variation across time but relatively modest variation across countries. Figure 1 (Panel A) displays the evolution of the time-varying and country-specific FI-measure defined in Equation (1). From 2001 until 2004, financial integration progressed relatively slowly compared to the second phase between 2004 and 2007, with the steepest increase around 2004.

- Insert Figure 1 here -

Using such a de jure measure is advantageous because the specific nature of transposing EU

that firms may worry to roll-over existing loans or accessing new debt (Acharya *et al.* 2011). This issue aggravates the importance of accessing external financing since such risks increase innovative firms' desire to raise financing at larger amounts (see Nanda and Rhodes-Kropf 2017).

Directives into domestic legislation mitigates endogeneity concerns along several dimensions. In particular, the Commission makes decisions on a supra-national level, rendering it unlikely for (primarily small) individual firms' actions to be related to country-specific initiatives (Schnabel and Seckinger 2019).[3] Moreover, the FSAP Directives resemble political decisions made in the late 1990s, so implementation is unlikely to reflect market responses several years later (Christensen *et al.* 2016). Similarly, the exact timing of the amendments can hardly be anticipated, and transpositions become effective on an individual country-specific basis only after passing domestic legislation (Kalemli-Özcan *et al.* 2010, 2013). In contrast to other legal amendments on the European level, EU Directives definitively result in changes in the law (unlike EU Recommendations and Comments), while the timing of their implementation is not strictly set at a pre-defined date (unlike EU Regulations). The time-consuming processes of modifying existing institutional structures, including the renewal and removal of agencies, infrastructure, and previous regulations, inhibit anticipation of the EU-level directives over time.

De facto measure of financial integration: The main analyses are complemented by a direct measure of financial integration that captures the evolution of integration in Europe. To quantify the *de facto* degree of financial integration, the analyses draw on price-based estimations of financial market integration used in macroeconomic analyses. This approach builds on the law of one price, which stipulates that assets with identical risk and cash flows should have the same price in integrated markets: The de facto measure captures the standard deviations in interest rates across monetary financial institutions' loans to non-financial corporations. It computes cross-country variation in the interest rates for both new loans and deposits with agreed maturity for all cases in which the counterparties are households or non-financial corporations, such as firms in the sample.

Specifically, I use a price-based indicator obtained from Hoffmann *et al.* (2020) that has been previously applied by central banks to monitor financial integration in Europe. The measure augments common indicators in the literature (e.g., Baele *et al.*, 2004) by decomposing financial integration in money, bond, equity, and banking markets. This feature is helpful in the context of this study as it allows me to track integration in the banking sector separately.[4] Using this de facto integration measure allows to validate the de jure measurement approach. Additionally, it is advantageous because it fluctuates across time, including non-zero integration values in the period before the FSAP.

Panel B of Figure 1 plots the disaggregated de facto integration measure across different sectors over the sample period. The key takeaways are: First, the overall increase in financial integration during that time is predominantly due to enhanced integration in the banking market.

[3] To my knowledge, the FSAP has no explicit mandate to promote innovation or patenting activities.

[4] The aggregate price-based indicator equals the unweighted average scores of these four segments. See Hoffmann *et al.* (2020) for an excellent description of the different measures.

Second, the de facto measure of banking integration closely resembles the de jure FI-measure of financial integration, as displayed in Panel A (pairwise correlation: 0.81). Both aspects underline the validity of the de jure measure and the empirical strategy as a whole.

3 Data and Measurement

3.1 Data sources and summary statistics

The main data set combines firm-level financial information from the ORBIS database provided by Bureau van Dijk and patent information from the PATSTAT database (Spring 2020 version). PATSTAT encompasses the universe of European patenting activities on a highly granular level and is provided by the European Patent Office. I use a direct link in the ORBIS IP database to merge the two databases. Further, I manually collect information on the FSAP implementation dates and additional macro-level control variables. Data on the price-based integration indicators are obtained from the European Central Bank.[5] Table A2 (Appendix A) lists and defines all variables used in this paper.

The main sample contains firms that filed at least one patent during the years 1999 to 2008. By choosing these years, the sample spans a broad time window around the implementation phase of the FSAP and avoids confounding factors relevant to firms' financing behavior, such as the Financial Crisis in 2009. Firms can enter and leave the database to avoid potential survivorship bias. Variables are winsorized at the 1 percent level to account for outliers. I exclude observations with zero or negative total assets and firms that cannot be categorized in industry classes. Further, I only consider firms from the private sector, excluding financial or service industries for which patenting is unlikely to be central to their business operations. The data samples eight countries, all of which are EU member states at the time of the FSAP drafting.

The final data is an unbalanced panel that comprises 118,724 firm-year observations (22,161 firms) and incorporates information on 703,378 patent applications. Panel A of Table 1 displays the sample distribution across countries, which reflects the different proportions of these countries in most cases. A notable exception is Italy, for which the ORBIS data has only relatively low coverage during the years of observation. Other than the factors mentioned above, there is no specific sample selection such that the final sample size is a function of patent ownership and coverage in the Orbis database.[6] By construction, the sample thus tends to focus on large patent-

[5] I am thankful for Manfred Kremer to provide the integration data published in Hoffmann *et al.* (2020).

[6] For example, while Italian firms constitute a large fraction of the population in the sampled countries, the share of patents from Italian firms is relatively low (see Table 1, Panel A). Consistently, Italian firms are expected to be underrepresented in the sample. Moreover, the coverage of Orbis varies across countries because of their country-specific data-gathering techniques. For example, French administrative firm-level data is relatively concise, which reflects the large share of French firms in the sample. Out of the original 15 EU member states in the late 1990s, Austria, Denmark, Greece, Ireland, Luxembourg, Portugal, and Spain were excluded due to low coverage in the financial data during the sample period.

intensive sectors and countries, such as France, Germany, and Great Britain, respectively. The analyses will show that excluding specific sample countries yields qualitatively similar effects.

- Insert Table 1 here -

Panel B of Table 1 displays summary statistics on key financial variables and basic firm characteristics. Again, these statistics reasonably reflect the actual European business landscape, which comprises predominantly small and medium-sized, well-established, and private firms. Firms have a median number of employees of 65, a median age of 17, and only about 5.0% of sample firms are listed corporations. Moreover, sample firms are fairly intangible-rich (13.5% median tangibility) and profitable (4.5% median return on assets).

3.2 Measuring inventions using patent data

The empirical part examines both patent quantity and quality dimensions. A straightforward approach for measuring firms' patenting activities is to calculate the number of (annual) *patent applications*, resembling the quantitative dimension of inventive output. Qualitative dimensions of firms' patenting activities are essential complement to this, as they directly relate to firm-level performance and growth (e.g., Hall and Harhoff 2012; de Rassenfosse 2013). Patent quality can be viewed as the size of the inventive step and determines the difficulty for competitors to invent around a patent, thus, lengthening the monopoly period for the patent holder (de Rassenfosse and Jaffe 2018). Specifically, the analysis distinguishes the technological quality, market value, and specific types of patents as qualitative dimensions.

The number of *citations* received and the number of *claims* included in patent applications serve as relevant dimensions describing the technological quality of a patent. As such, high-quality patents are expected to receive more citations, reflecting the impact of a patent on subsequent inventions (e.g., Trajtenberg 1990; de Rassenfosse and Jaffe 2017). Consistent with prior literature, I count all citations within the first seven years after application. Moreover, the number of claims included in a patent application is positively associated with patent quality, as they resemble the boundaries of the property right (Marco *et al.* 2019). I normalize the number of claims in an application by dividing them by backward citations (i.e., references included in a patent description) to control for differences in the scope with respect to the prior art.

The empirical analyses also consider the market value of patents by tracking the geographical scope of patent protection and the number of years a patent is alive.[7] These two dimensions are cost-relevant and, thus, reflect patent value without necessarily being related to technological features (see Hall *et al.* 2005; de Rassenfosse and Jaffe 2018). As such, the costs of maintaining a patent portfolio increase with its size, the number of jurisdictions in which protection is sought,

[7] I do not use stock-market-related patenting measures (e.g., Kogan *et al.* 2017) since the vast majority of sample firms are not listed. While it is possible to approximate market values by matching on observable patent characteristics, patentees' complementary assets are peculiar for small firms, questioning such an approach.

and patent age. Firms' willingness to repeatedly incur these costs indicates the underlying patent value (Schankerman and Pakes 1986; Harhoff *et al.* 2009). Specifically, literature associates more valuable patents with a large international scope, the so-called *family size* (Harhoff *et al.* 2003; Hall *et al.* 2005), and with a higher number of *renewals* (de la Potterie 2010; Gill and Heller 2022). To quantify these two dimensions, I count the ex-post-determined maximum number of jurisdictions and the frequency of patent renewals.

The analyses also distinguish between explorative and incremental patents to elicit more directly on different patent types. Both types are value-relevant from a firm perspective. Explorative inventions have groundbreaking potential, possibly delivering high returns, and are characterized by risky, large inventive steps (Beck *et al.* 2016). In contrast, incremental inventions potentially deepen revenue-generating capacities of existing inventions through successive but steady improvements (Henderson 1993). As such, incremental patents are relatively marginal improvements with no significant impact on follow-up inventions. I thus compute the two types based on whether patents have a high technological impact and diversity.

Table 2 summarizes the definitions of all patenting dimensions and provides corresponding summary statistics. To map the patent-level information to the firm-level financial data, I aggregate the individual patent measures on a firm-year level that matches the panel structure of the financial information. Appendix B provides further details on the patenting dimensions, their construction, and mutual relations.

- Insert Table 2 here -

The statistics show that patenting activities vary significantly on the firm level, both in terms of patent quantity and quality. While some firms file no patents in a given year, (few) others apply for several thousand patents. Further, the quality distributions of patents are notably skewed towards low-impact patents. Incremental patents make up a significant fraction of all patents (45%), while a comparably small fraction of patents has a high impact on subsequent inventions (6%) or can be considered explorative (2%).[8] These observations are in line with previous literature that indicates high skewness in the distribution of patent variables (e.g., Gambardella *et al.* 2007; Deng 2007). In addition, patenting activities are also heterogeneous across and within countries. As shown in Table 1, large countries (i.e., France, Germany, and Great Britain) are dominant in terms of patent filings. Similarly, patenting activities cluster in specific sectors (see Table A3, Appendix A); For instance, the manufacturing sector accounts for the majority of patents (64%). Overall, descriptive statistics suggest that the sample comprises a representative set of European patenting firms and industries that recognizes structural cross-country and cross-sectoral differences in the propensity to patent.

[8] The majority of patents is neither incremental nor explorative and can be considered as a benchmark group. The approach of not classifying patents into a binary category has the advantage of observing and thus analyzing these types independently. A binary classification would have the mechanical constraint that all patents which are not incremental would be explorative by default and vice versa.

4 Empirical strategy and main results

4.1 Empirical strategy

Defining the model: The objective of the empirical analysis is to assess the impact of the FSAP on firms' financing and patenting activities. The methodology follows an established tradition of examining policy reforms or shifts in the macroeconomic environment in the spirit of a generalized difference-in-differences (DID) approach. Here, variation in financing conditions across time arises from the implementation of the banking-related FSAP Directives. The FI-measures introduced in Section 2.2 operationalize the significant shift in financial market integration caused by the FSAP, which affected firms across countries with different intensities over time. As a source of cross-sectional variation, the setting exploits that the legal amendments and, thus, the changes in the credit supply are most relevant only for some firms. As outlined in Section 2.1, financially constrained firms can be expected to respond disproportionally to changes in financial market integration (i.e., an assumption that will be validated in the analyses). Consistent with this, I utilize cross-sectional heterogeneity regarding firms' propensity to respond to the legislative amendments and compare the effects of the FSAP on debt financing and patenting activities across firms with high and low ex-ante financing constraints. Formally, the baseline specification reads:

$$Y_{ict} = \beta_1(FI_{ct} \times Constrained_i) + \beta_2 X_{it} + \beta_i + \beta_{ct} + \varepsilon_{ict} \qquad , \tag{2}$$

where the dependent variable Y_{ict} is either the financing or the patenting activity of firm i, located in country c in period t. In the main specification, financing activities are the logarithm of total debt or firms' interest burden. Patenting activities refer to any of the patent measures defined in Table 2. $Constrained_i$ is a dummy variable indicating the exposure to the FSAP and equal to one for ex-ante financially constrained firms as defined below and zero otherwise. FI_{ct} is the country-specific, *de jure* integration measure as defined in Equation (1). The coefficient of interest (henceforth also: DID estimate), β_1, captures the (local) average effect of financial integration, namely the difference in financing and patenting activities between ex-ante financially constrained and unconstrained firms as the effects of the FSAP unfold. I control for capital structure determinants as commonly applied in related literature (e.g., Graham and Leary 2011). Specifically, the vector of controls, X_{it}, includes firm size, asset tangibility, profitability, and cash flows. In addition to this, the panel structure of the data allows controlling for unobserved heterogeneity across firms and country-specific time trends or macroeconomic conditions by including firm- and country-year fixed effects (β_i and β_{ct}, respectively). The single regressors of the interaction term are omitted since, otherwise, perfect multicollinearity arises due to the fixed effects specification. I cluster standard errors by firms in the main specification. The results are not sensitive to clustering by the country- or country-industry level.

Regressions with financing outcomes as dependent variables are estimated using OLS. The patent analyses use Poisson pseudo quasi-maximum likelihood (PPQML) regressions with multiple levels of fixed effects, following (Correia *et al.* 2020). Using PPQML is common in estimations with count variables as dependent variables, such as patenting activities. It accounts for the highly-skewed distribution and the issue of many zero observations in firm-level patenting activities (Cohn *et al.* 2022).[9]

The main specification measures financial constraints using the S&A index proposed in Hadlock and Pierce (2010). The index predicts constraints as a function of firm size and age. Choosing this measure has the advantage that it applies to a broad set of firms and can be calculated for non-listed firms.[10] In the context of this study, this characteristic is essential because most sample firms are small and medium-sized private firms. I classify more or less exposed units, considering firms below the country-specific median S&A value as financially constrained and vice versa. This relatively broad classification scheme acknowledges the limited precision of standard measures of financing constraints (see Farre-Mensa and Ljungqvist 2016) and follows related literature (e.g., Duchin *et al.* 2010; Cerqueiro *et al.* 2017). Further, the classification considers firms' pre-integration levels of financing constraints to mitigate endogeneity concerns regarding variation in firm characteristics once the integration process is initiated.

Panel A of Table A4 (Appendix A) displays descriptive statistics on the main variables for ex-ante constrained and unconstrained firms. By definition, *Constrained* firms are younger and smaller, whereas several other variables are comparable across groups, such as asset tangibility or profitability. To mitigate concerns that observable differences or firm dynamics drive the main findings, I conduct several robustness tests, including an alternative, industry-level specification of more or less affected firms in Section 4.4.

Plausibility checks: Descriptive statistics support the empirical strategy, showing differential responses of firms to the FSAP, depending on their degree of ex-ante financing constraints. The process of financial integration relates positively to firms' debt financing, both on an extensive and intensive margin and particularly for ex-ante financially constrained firms. Comparing the averages for all years in which $FI < 0.2$ with years in which $FI > 0.8$, about 9% of ex-ante constrained firms with no bank debt prior to the FSAP, but only 2% of ex-ante unconstrained firms obtained bank debt by the end of the integration process (p-value: 0.000). Moreover, previously constrained firms also raise their use of debt on the intensive margin. Ex-ante constrained firms' percentage change in bank loans outstanding is significantly greater (32.2%) compared to the change in debt of unconstrained firms (23.2%; p-value: 0.012).

[9]Importantly, PPQML avoids the problems that arise when estimating linear regressions of the log of outcome plus 1, as applied in many empirical studies on patenting outcomes. Most severely, such estimations often yield results that cannot be directly interpreted and suffer from severe biases (see Cohn *et al.* 2022). Using PPQML, Equation (2) is formally expressed by: $E(Y_{ict}) = exp[\,\beta_1(FI_{ct} \times Constrained_i) + \beta_2 X_{it} + \beta_i + \beta_{ct}] + \varepsilon_{ict}$.

[10]This is not the case for most other financing constraint measures, such as the Kaplan-Zingales or the Whited-Wu index, which typically comprise information only available for publicly listed firms, such as dividend payouts.

As a next step, I adopt the convention from related literature and assess common trends as a necessary condition for the empirical strategy. I acknowledge that parallel pre-trends can only partially be tested empirically. Hence, analyzing pre-trends is only a first but – nonetheless – important step to address concerns that differences between the comparison groups in the years before the FSAP drive the main results. As a first test, I estimate a specification similar to Equation (2) using a subsample of pre-treatment periods. Instead of the FI $\times$ *Constrained*-interaction, it includes interactions of time dummies for each year prior to the FSAP with the *Constrained*-indicator. Panel B of Table A4 (Appendix A) plots respective coefficients, none of which is statistically significant. Second, I follow Angrist and Pischke (2008) by including a time trend variable (i.e., a year count capturing the general anticipatory pre-treatment movements) and its interaction with the *Constrained*-dummy using the same subsample of pre-treatment periods. Panel C of Table A4 (Appendix A) displays the coefficients of these regressions using bank loans, patent filings, and patent quality variables as dependent variables. Consistent across specifications, coefficients are statistically insignificant. Summarized, this set of tests shows that ex-ante constrained and unconstrained firms are likely to follow similar trends regarding the main outcome variables in the immediate years before the FSAP.

4.2 Baseline results

4.2.1 The FSAP and debt financing

I begin by analyzing the effect of the FSAP on firm-level debt financing activities. Panel A of Table 3 presents estimates on different variants of Equation (2) using the logarithm of bank loans as the dependent variable. In Column I, the regression is similar to the main specification but includes industry fixed effects and country-level macroeconomic controls instead of firm- and year fixed effects such that the level variables of the interaction term, FI and *Constrained*, are estimated. The coefficient of the interaction term is positive, large, and significant at the one percent level, implying a disproportional increase in the use of debt after the adoption of the FSAP Directives comparing ex-ante constrained firms relative to unconstrained firms. The positive coefficient on FI shows that the post-integration phase is generally associated with higher debt levels. The negative and significant coefficient on *Constrained* suggests that, on average, ex-ante constrained firms have less bank debt. Comparing the size of the estimate with the DID estimate (which is larger) indicates that the wedge between ex-ante constrained and unconstrained firms closes as financial market integration progresses.

Column II displays estimates on the baseline specification and confirms the first findings from Column I. The DID estimate is again highly significant and positive. The size of the coefficient implies an economically meaningful disproportional increase of bank loans of about 12% from pre- to post-FSAP implementation for ex-ante constrained firms relative to unconstrained firms. To illustrate, the average amount of outstanding end-of-the-year bank debt of constrained firms before the initiation of the FSAP amendments is about 120,000 Euros. Hence, the coefficient of the interaction term (0.118) corresponds to a relative increase in debt of approximately 13,500 Euros per year. This finding is qualitatively similar when using the de facto measure of financial integration (Column III) and robust to excluding the time-varying covariates (Column IV), which is a standard validity check in the DID literature (see, Sant'Anna and Zhao 2020).

- Insert Table 3 here -

Next, I turn to the effects of the FSAP on the costs of debt. Estimates confirm that financial market integration affected borrowing conditions. Columns I and II of Table 3 (Panel B) display regression estimates explaining the impact of the FSAP on firms' interest burden. In both specifications, the coefficients of the interaction terms are negative and highly significant, showing that the FSAP is associated with a disproportional decrease in interest burdens for ex-ante financially constrained firms. The effects are also economically significant. As such, the coefficient from the main specification in Column II suggests a 6% stronger decline in interest burden (equivalent to 0.6 percentage points) for the average ex-ante constrained firm relative to unconstrained firms when moving from pre- to post-FSAP periods.[11]

Moreover, the effects of financial integration on interest rates are linked to the positive effect on the use of debt. In Columns III-VI of Table 3 (Panel B), I test the heterogeneous effects of the FSAP on debt financing activities depending on whether firms benefited from lower interest burdens using two approaches. First, I calculate changes in firms' average interest burden, comparing pre- and post-FSAP levels, and use these values to reestimate the baseline specification separately for firms with lower (Column III) and without lower (Column IV) average post-FSAP interest rates. The positive effect of the FSAP on bank debt primarily arises for firms with relatively lower interest burdens after the FSAP. As a second approach, I use triple differences estimations by including the *Beneficiary*-dummy and its interaction with the DID components, FI and *Constrained*, to the main specification. *Beneficiaries* equals one for firms with lower post-FSAP interest burden and zero otherwise. Results in Columns V and VI are qualitatively similar to before and show that the positive effect of the FSAP is mainly attributable to firms with decreasing costs of debt. Hence, the above results provide robust evidence that the FSAP significantly affected firms' debt financing activities: Ex-ante financially constrained firms disproportionally raise their use of debt and face lower levels of interest burden comparing pre- and post-integration levels relative to those of ex-ante unconstrained firms. These findings reflect the idea that financial market integration mitigates financing constraints by putting downward pressure on interest rates and, thereby, stimulating the use of debt.

Table A5 (Appendix A) displays a series of tests that demonstrate the robustness of these estimates. The results also apply when using the de facto measure across specifications (Panel A)

[11] The average treatment effect equals -0.0633 ($= -0.005/0.079$) since ex-ante constrained firms' average pre-treatment interest burden is about 7.9%.

and using debt-to-asset ratios as the dependent variable (Panel B). Importantly, the estimates are consistent when using different variants of the de jure financial integration measure and, in particular, when focusing on specific directives (see Panel C).[12]

4.2.2 The FSAP and patenting

Patent quantity: I proceed by analyzing the effect of the FSAP on firms' patenting activities. Panel A of Table 4 displays results from different variants of the baseline specification estimated using PPQML with multiple levels of fixed effects and patent filings as the dependent variable. Column I displays a simple regression explaining the relation of the FSAP on firms' annual patent applications, including a set of firm- and macro-level controls. In this specification, the coefficient on the FI-measure is insignificant, suggesting that the average firm in the sample did not change their patent filing activities in response to the FSAP. However, distinguishing between ex-ante constrained and unconstrained firms shows that the adoption of the FSAP had a positive effect on the number of patent filings of ex-ante financially constrained firms. Columns II and III display estimates on specifications equivalent to the baseline regressions on financing activities (Columns I and II in Table 3). The coefficients of the interaction term FI $\times$ *Constrained* are positive, large, and significant at the one percent level. The estimated effects are economically significant in magnitude. For example, the point estimate of 0.224 in Column III suggests that moving the average firm from the pre- to the post-integration results in a 25% higher likelihood of filing a patent.[13]

- Insert Table 4 here -

Using different model specifications analog to those in Panel A of Table 3 produces very similar estimates in size and significance (see Columns IV and V). Previous results are also unlikely to be driven by specific variable definitions: In Table A6 (Appendix A), Panel A shows that results are not sensitive to applying alternative definitions of the FI-measure, the cutoff to determine financing constraints, or the dependent variable. Overall, these results suggest that the FSAP increased patent filing activities of firms that were ex-ante more financially constrained. In other words, firms that disproportionally raised more debt throughout the financial integration process also filed disproportionally more patents.

Patent quality: Panel B of Table 4 illustrates the main findings on patent *quality* outcomes. It displays the DID estimates from the baseline specification equivalent to Column III in Panel

[12]The first alternative measure is a binary indicator distinguishing pre- and post-2004, i.e., the year in which the de facto variable spikes and most Directives were implemented (see Figure 1). This measure is likely inflated, as it assumes that all of the integration effort occurs at once. However, it is a common way in the DID literature to test for the sensitivity of the effects to potentially staggered treatments (see Baker *et al.* 2022). Second, I compute the FI-measure using only the three Directives with the official deadline in 2004. Third, I compute an FI-measure that uses the two latest directives, the Capital Requirements Directives, yielding slightly smaller effect sizes that potentially mirror the importance of considering the combination of policy changes.

[13]The rate ratio is obtained from $e^{\beta_1} = e^{0.224} = 1.2511$, i.e., the multiplicative increase in the rate of patent filings of ex-ante constrained firms compared to ex-ante unconstrained firms. Here, β_1 denotes the DID estimate.

A, using the patent quality dimensions as the dependent variables. In contrast to the effect on the number of patented inventions, the impact of the FSAP for ex-ante financially constrained firms on the different qualitative dimensions is rather ambiguous. The technological quality of patented inventions moderately increased or, at least, remained similar: There is a statistically significant positive effect on forward citations but not on the claims (Columns I-II). In contrast, the estimates for the market value proxies (i.e., family size and patent renewals) are negative and statistically significant (Columns III-IV). However, in terms of economic magnitude, these effects on the market value are relatively small compared to those on patent filings. For example, the coefficient on family size suggests a 6% (= 0.246/4.006) relative decline after the FSAP adoption for ex-ante constrained firms relative to unconstrained firms.

Estimations explaining the effects of the FSAP on the generation of specific patent types are consistent with the previous estimates. The average share of incremental or explorative patents among all filings is not affected by the FSAP (Columns V-VI). Decomposing these broader patent types into their two subclasses (high impact and technological diversity) mirrors the previous results of a positive effect on forward citations and a negative effect on market value (Columns VII-VIII). As such, the FSAP induced a modest positive effect on the number of high-impact patents and a weak negative effect on the technological diversity of patents filed. Panel B of Table A6 (Appendix A) summarizes these results graphically.

These results are robust to using firm-year maximum and normalized patenting values, as displayed in Panel C of Table A6 (Appendix A). This is important, first, because the effects on the average values of patenting dimensions may not fully reflect changes in the upper tail of the quality distribution (i.e., when using maximum values of the quality indicators). Second, patenting activities are technology-specific and thus expressions of the quality measures may have different meanings across industries. Yet, for both adjustments the results are qualitatively similar to those before, supporting the previous findings.[14]

Overall, the analyses on the quality and types of patents show a more nuanced picture compared to exclusively considering the number of patent filings. Ex-ante financially constrained firms which significantly raised patenting activities filed patents of lower technological diversity and market value. At the same time, the technological quality and the general occurrence of explorative and high-impact patents increased. While these results partially suggest a quantity-quality tradeoff in line with a relaxed disciplining effect, the estimates are relatively small and sensitive. Hence, a more conservative interpretation is that ex-ante financially constrained firms generated more patents of relatively similar quality when comparing pre- and post-integration levels. As such, these results cannot robustly confirm a disciplining effect of being financially constrained but instead suggest a beneficial impact of mitigating financial constraints to enhance

[14]The findings are also robust to i) using lagged values of the FI-measure, ii) weighting the FI-measure by countries' GDP, iii) using patent originality (Hall *et al.* 2001) as an alternative quality dimension (unreported).

patenting activities, consistent with the credit-supply effect.

4.2.3 Validation tests: Financing demand, growth and spatial dynamics

Next, I test the validity of the main results along several broad dimensions. Plausibly, firms with a high ex-ante dependence on external financing among financially constrained firms should respond stronger to the FSAP. This is a key identifying assumption and echoes research showing that firms with limited access to financial resources but relatively high demand for financing are exposed to shifts in the supply of external debt financing (e.g., Holmström and Tirole 1997).

In Panel A of Table 5, I examine this proposition by re-estimating the baseline regressions explaining both debt financing (Columns I-III) and patenting filings (Columns IV-VI). Specifically, I exploit cross-sectional heterogeneity regarding firms' demand for external financing using the RZ index (see Rajan and Zingales 1998). The measure relates the free cash flow of firms to their expenditures; firms with relatively higher expenditures are expected to be more reliant on external financing.[15] I split the sample and separately estimate the baseline specification for firms with an above- (Columns I and IV) or below-median RZ score (Columns II and V). Across specifications, results for firms with low ex-ante RZ scores are statistically insignificant and relatively small (0.022 and 0.095) compared to firms with high RZ scores (0.152 and 0.329). The coefficient for the interaction term FI $\times$ *Constrained* is significant at the one percent level in the latter case. As an alternative specification, I use a triple difference, interacting the FI $\times$ *Constrained*-term with a $RZscore^{\text{high}}$ indicator that equals one if a firm has an above-median RZ score prior to the FSAP and zero otherwise. Including this regressor, the DID estimate turns insignificant, while the coefficient on the triple interaction term is large, positive, and highly significant (see Columns III and VI). These findings are consistent with the presumption that the overall effects should be stronger for firms with a high demand for external debt financing.

- Insert Table 5 here -

Second, I address concerns that firms' lifecycle dynamics drive the main results. Indeed, growth patterns are key determinants for patenting activities across firms and within firms over time. While all previous estimations control for firm size and time-invariant, firm-specific effects by including firm fixed effects, this does not per se rule out the possibility that growth dynamics confound the baseline effects. I use a "horse-race" approach to compare the effects of the FSAP for firms with high growth rates to those for ex-ante financially constrained firms in the baseline specification. To do so, I estimate specifications that are similar to the baseline regression in Equation (2) but add an interaction term of the FI-measure with a dummy variable that flags high-growth firms ($Growth^{\text{high}}$). High-growth firms have above-median levels of growth,

[15]Specifically, the RZ score is computed by: $RZscore = (capex - cf)/capex$ with firms' investments (capex) related to their cash flows (cf) during the pre-treatment period (i.e., $FI = 0$).

measured during the pre-treatment period. For robustness, I use three dimensions of growth, i.e., in terms of total assets, total employment, and wage payments.

Panel B of Table 5 shows that adding these interaction terms to the baseline specification does not affect the sign, size, or significance of the DID estimate, which remains positive, economically sizable, and highly significant. In contrast, the coefficients on the interaction term $FI \times Growth^{\text{high}}$ is relatively small and insignificant for all three growth specifications and for regressions using both bank debt (Columns I-III) and patent filings (Column IV-VI) as the dependent variables. Hence, it appears unlikely that firms' growth dynamics and not financial market integration drive the observed changes in financing and patenting activities.

Third, I conduct additional analyses that control for regional characteristics to mitigate concerns about spatial dynamics within countries. The baseline regressions account for country-specific trends and firm locations by including firm fixed effects. However, they are agnostic about regional heterogeneity, such that positive agglomeration effects unrelated to the FSAP may affect the main results. Indeed, geographical heterogeneity is a crucial determinant for innovative activities as it shapes knowledge spillovers (see Autant-Bernard *et al.* 2013; Montmartin *et al.* 2018). To account for such spatial dynamics, I reestimate the baseline regressions explaining firms' use of bank loans and patent filings and include region and region-time fixed effects. I measure regions on the NUTS3 level, a very granular locational unit. For example, the eight sampled countries are divided into 825 NUTS3 regions. Table A7 (Appendix A) presents the corresponding estimates and shows that they are very similar in size and statistical significance compared with the main results. Like the previous tests, these results confirm the main results.

4.3 The timing of the effects and robustness tests

4.3.1 The sequential effects of the FSAP on debt financing and patenting

Providing additional insights on the timing of the main effects is important. Financial market integration is a process that evolves over time, and the impact of such legal changes on firm-level activities typically occurs with a lag (Kalemli-Özcan *et al.* 2013; Christensen *et al.* 2016). Against this background, I analyze the dynamic treatment effects of the implementation of the FSAP Directives on financing and patenting activities using an event-study-like design. I formally estimate:

$$Y_{ict} = \alpha_k \left(\sum_k FI_{kc}^{\text{stage}} \times Constrained_i \right) + \alpha X_{it} + \alpha_i + \alpha_{ct} + u_{ict}\,, \tag{3}$$

where Y_{it} denotes the firm-level financing or patenting outcome in period t and $stage_{kc}$ refers to the stage k of financial integration in country c.[16] For robustness, I use two different specifications

[16]The remaining variables are defined as in the baseline specification in Equation (2). Again, the patent-level regressions use PPQML, i.e., it is modified as $E(Y_{it}) = exp(\Gamma)$ with Γ abbreviating expression Equation (3).

to define the integration phase. First, I measure the calendar years relative to the country-specific first year in which the *de jure* FSAP measure is larger than zero, i.e., $FI > 0$. Second, I analyze the impact of the FSAP distinguishing different phases of the financial market integration. Here, the variable $stage_{kc}$ distinguishes between pre-treatment ($FI_{ct} = 0$), early stage ($0 < FI_{ct} < 0.3$), medium stage ($0.3 < FI_{ct} < 0.6$), late stage ($0.6 < FI_{ct} < 0.9$), and post-treatment ($FI_{ct} = 1$) periods. In both specifications, the reference period is the last year before the FI-measure turns positive.

Figure 2 plots the estimated coefficients on the interaction terms between treatment and integration-stage dummies, i.e., α in Equation (3). Panel A displays the estimates from regressions that use calendar years to approximate the different stages of financial integration. For the years t-1 and t+1, the DID coefficients are insignificant for both outcome variables. However, for regressions that use bank debt as the dependent variable, the coefficients increase in size and are statistically highly significant as of t+2. Resembling a lagged response in the patenting activities, the dynamic DID estimate for regressions explaining patent filings turns positive and statistically significant only in year t+3.

- Insert Figure 2 here -

Panel B repeats this analysis but uses the different phases of the integration process as outlined above. Results mirror the estimates from Panel A and show that the positive effect of the adoption of the FSAP on firms' use of debt financing starts to unfold in the early integration phase. In contrast, the positive impact on patent filings arises in the later stages of financial integration. These results are consistent with the view that firms adjust their research activities in response to a shift in funding with a delay because of relatively high adjustment costs (e.g., Brown *et al.* 2009). Moreover, the findings on the dynamic effects of the FSAP show that financial integration first affects firms' debt financing activities and only then leads to a lagged increase in patent filings.

4.3.2 DID-specific tests

The timing of the policy change itself is a natural concern with the estimation specification. As such, settings with staggered changes in the law that deploy the canonical two-way fixed effect DID estimations have raised debates in applied econometric research (e.g., Goodman-Bacon 2021; Roth *et al.* 2023). Estimations may suffer from severe biases once late-adopting firms serve as controls for early-adopting firms. In my setting, it would be problematic if firms in late-adopting countries (not-yet-treated units) serve as controls for firms in early-adopting countries, especially since the FSAP affected financial integration to varying degrees across time. Previous analyses already implement standard validity checks from the DID literature as discussed, e.g., in Baker *et al.* (2022), such as omitting time-variant controls, using binary treatment variables, and estimating the dynamic treatment effects in the previous event-study analyses. Consistent with this, the previous analyses have shown that the estimates are also robust to using the de facto measure of financial integration as an alternative treatment variable. This outcome is important because the de facto measure mutes cross-country variation in financial integration, such that there are no early- or late-adopting countries by construction.

In addition to this, there are several reasons why the specific modeling approach of the integration variable and the general empirical setup make it unlikely that the common concerns about staggered DID analyses apply in the context of this paper. First, dynamic treatment analyses require further diagnostics mainly if treatment timing varies across a long period (Baker *et al.* 2022). In fact, the implementations of the FSAP Directives occur in short sequence: Most laws were implemented in 2004, with 2002 and 2003 being the initial adoption years. Second, the mutual dependence of financial integration as proposed in related literature and adapted in the FI-measure resembles a coordinated, multilateral process with limited cross-country variation (e.g., Kalemli-Özcan *et al.* 2013). For this reason, Equation (1) imposes that financial integration is a function of amendments to domestic *and* foreign law, which significantly lowers cross-country variation, albeit not entirely removing it (see Figure 1). For example, almost all sample countries surpass the 0.25, 0.5, 0.75, and 1.0 thresholds of the integration measure in the same years (see Panel B of Figure A1, Appendix A). Third, issues with two-way fixed effects DID estimations are specific to cases in which a small share of units are never treated (Baker *et al.* 2022). Arguably, all firms are subject to the FSAP amendments. However, a significant proportion of about 60% of firms in the main specification remains less affected (i.e., ex-ante unconstrained firms). In combination, these aspects suggest that the main specification resembles a weakly staggered, dynamic treatment setting. In fact, recent advances in econometrics emphasize the conceptual and practical benefits of such dynamic treatment analyses (De Chaisemartin and d'Haultfoeuille 2020; Sun and Abraham 2021).

Nonetheless, given the prevalence of the potential econometric issue, I conduct a series of robustness tests to further mitigate concerns regarding the timing differences in the adoption of the FSAP Directives. What these tests have in common is that they aim at explicitly ruling out erroneous comparisons of late- and early-adopting firms. To this end, I remove "non-clean" controls by running split sample regressions on subsets of countries with similar patterns in the *de jure* measure of financial integration. Within countries, there is no variation in the FI-measure. Thus, I estimate regressions separately for firms located in countries that adopted the first FSAP Directive early versus those adopting late (i.e., in 2002 versus 2003, respectively), for firms with and without lagged adoption during the implementation phase (i.e., countries with below average FI-values in 2004, 2005, or 2006), and for a combination of these two criteria. Using these subsamples, Panel A of Table 6 presents the results of estimating the baseline regression explaining firms' financing (Columns I-IV) and patenting activities (Columns V-VIII), respectively. The estimates are qualitatively similar to the baseline results, both in magnitude and significance, suggesting that bad controls are unlikely to bias the main results. Specifically, the results apply for early adopting countries (Columns I and V), i.e., countries most prone to suffer from non-clean controls (Goodman-Bacon 2021). As a positive side effect, this exercise also addresses concerns that single countries account for the main results.[17]

- Insert Table 6 here -

On top of this, I run a more standardized procedure of testing the "non-clean" controls. I use the modified, stacked DID method of Callaway and Sant'Anna (2021) to show that the previous findings are not specific to the design of the tests. By default, the test only uses "clean" controls, i.e., it excludes firms that are not-yet-treated and keeps only never-treated units on a cohort-by-cohort basis. Cohorts are firms that share the same initial treatment year. The test first estimates the average treatment effects for each treatment cohort and then aggregates them. The initial treatment year in the empirical setting of this paper could plausibly refer to any year during the early phase of the FSAP adoption period (as illustrated in Figure 2). Hence, I repeat the analysis using a set of different FI-measure thresholds to mark the country-specific, initial treatment year. Panel B of Table 6 displays the results, using debt financing and patenting activities as the dependent variables. In most specifications, the estimates are positive and statistically significant. Notably, the effects on debt financing are stronger for lower FI-measure thresholds, while the effects on patenting outcomes are stronger for higher FI-measure values. These results reflect the sequential rise in debt financing and delayed response in patent filing activities, corroborating the event-study type regressions in the previous section. Figure A2 (Appendix A) graphically illustrates the dynamics of the treatment effects.[18]

The current debates in the econometric literature emphasize that addressing methodological features of two-way fixed effect DID estimations is essential in an empirical study. While previous results already mitigate concerns regarding the validity of the methodology along several dimensions, this section takes an additional precaution by implementing a set of state-of-the-art tests on the validity of the baseline estimates. Uniformly, these tests confirm the previous findings. Although empirical concerns can never be fully eliminated, the amount of evidence emphasizes that potential issues with the empirical strategy are unlikely to drive the main findings.

[17] For example, France is a late-adopting country that comprises a large share of the sample. Hence, the results in Columns I and IV show that the baseline results are unaffected by excluding France from the main sample.

[18] There are some alternatives to the stacked-DID approach by Callaway and Sant'Anna (2021), for example, the approach by Cengiz *et al.* (2019) constitutes a potential substitute (Baker *et al.* 2022). However, Callaway and Sant'Anna (2021) is particularly suitably setups that use panel data with a relatively short timeframe, few treated groups, and, particularly, in contexts in which concerns about parallel trends across long periods prevail (see Roth *et al.* 2023). These attributes apply to the empirical setup of this paper. Panel C of Figure A2 shows that using the approach suggested in Cengiz *et al.* (2019) yields similar estimates.

4.3.3 Placebo analysis – The introduction of the Euro

This subsection addresses a remaining threat to the empirical strategy: Other contemporaneous events unrelated to financial integration in the banking sector might have triggered the same firm responses. Moreover, certain macroeconomic conditions may have shaped firms' financing activities, particularly since the FSAP Directives become effective throughout several years of a business cycle. To address these concerns, I repeat the baseline analysis using an alternative sample time frame, which is comparable regarding macroeconomic conditions and financial integration but is not accompanied by improved access to bank financing.

In particular, I investigate the introduction of the Euro as bank money in 1999, which fulfills these criteria for multiple reasons. First, the overall macroeconomic conditions are comparable around the Euro- and the FSAP introduction. As illustrated in Figure A3 (Appendix A), GDP rates follow a cyclical pattern, including an early growth phase and a late phase of economic decline. 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 spurred intra-Eurozone investment by eliminating or at least significantly lowering exchange rate risk and other transaction costs (see Haselmann and Herwartz 2010). Third, while fostering financial integration, the introduction of the Euro had only a limited effect on the degree of integration in the banking market (e.g., Cabral *et al.* 2002; Baele *et al.* 2004). More specifically, Haselmann and Herwartz (2010) find that the Euro did not effectively reduce information asymmetries between firms and banks. Aggregate statistics support these assessments (e.g., Figure A1 in Appendix A). Hence, the impact of the Euro's introduction on borrowing conditions for European firms should be much lower than the effect of implementing the FSAP.

To detail these relationships, I extend the baseline sample by the years up to 1996 and remove the last five years (2004-2008) of the data to maintain a comparably symmetric time window around the treatment event and to avoid the placebo sample from overlapping with years of significant FSAP impact. Again, the analyses distinguish ex-ante financially constrained and unconstrained firms, measured by the average pre-Euro S&A score. All other variables are computed as in the baseline setting except for the FI-measure. The analyses use two variants of the placebo treatment variables to mitigate concerns that the results are driven by one specific modeling approach and, in particular, to account for timing differences between the FSAP and the Euro introduction. While the transposition of the FSAP Directives gradually took place, the Euro introduction refers to a specific date. The first placebo treatment variable (FI^{placebo}) is a dummy variable equal to one after 1999. This measurement approach quantifies the launch of the Euro as a one-time event. The second specification uses a continuous variable, which is a linear transformation of the original *de jure* integration measure (Equation 1) but uses 1999 as the year in which the annual average FI score surpasses 0.5 for the first time. This treatment definition mimics the phases of FSAP integration and captures effects more closely related to the changes in the macroeconomic conditions throughout the sample period.

- Insert Table 7 here -

Table 7 displays regressions that estimate the effect of the Euro introduction on financing and patenting activities. Columns I and II display estimates explaining firms' use of debt similar to the first two columns in Table 3 (Panel A) but use the placebo setting and include only firms from countries that adopted the Euro as the official currency. The coefficients of the components of the interaction term $FI^{\text{placebo}} \times Constrained$ and, in particular, the DID estimate is small, negative, and statistically insignificant (Column II). This result is robust to using a sample of firms from all countries in the original sample, i.e., irrespective of whether they adopted the Euro (Columns III and V). Using the placebo-treatment variable that mimics the dynamic adoption of the FSAP Directives also yields very similar results (Columns IV and V). These findings verify that the introduction of the single currency in 1999 did not have a comparable effect on the banking sector compared to the adoption of the FSAP amendments. To further illustrate this, Columns VI and VII display estimations that use the number of patent filings as a dependent variable. The coefficients of the interaction term are positive but relatively small and insignificant.[19] Again, these analyses underline that the introduction of the Euro did not have comparable effects on firms' financing and subsequent patenting activities, despite marking a major event of financial market integration embedded in similar macroeconomic conditions. Taken together, the results are consistent with the identifying assumptions and strengthen the validity of the empirical strategy.

4.4 Matched sample: Integration and industry-level debt dependence

Methodology: The previous results show that more financially constrained firms respond disproportionally to financial market integration. Measuring financing constraints via the S&A index is advantageous because it directly flags firms with a high propensity to respond to financial integration and is applicable to small private firms – unlike most other measures used in the literature on financing constraints. Even though several tests show that omitted variables are unlikely to bias the previous results, there are valid concerns with using observable firm characteristics, such as firm size and age, as identifying cross-sectional variation. As such, observed and unobserved differences across ex-ante constrained and unconstrained firms may be endogenous to variation in their ex-post financing and patenting activities.

Against this background, this section introduces an alternative specification to classify firms as more or less affected by the FSAP. I follow a commonly applied estimation approach and distinguish firms according to ex-ante industry-level differences in bank dependence (see, e.g.,

[19] Table A8 (Appendix A) displays estimates using patents' technological quality and market value measures as dependent variables. Estimations are statistically insignificant across specifications.

Duchin *et al.* 2010; Cornaggia *et al.* 2015; Cerqueiro *et al.* 2017). This approach is suitable for several reasons. Most fundamentally, it is independent of observable firm characteristics and, in particular, independent of their size and age. At the same time, the channel through which firms are affected by increased financial integration is very similar when using bank-dependence and financing constraints: Improvements in financing conditions are amplified for firms with a high dependence on debt external financing (e.g., Holmström and Tirole 1997; Becker and Ivashina 2014). Indeed, previous results in Section 4.3 suggest that this mechanism applies in the present setting. As another advantage, industry-level measures of debt dependency are not determined by individual firm characteristics, which is key for mitigating endogeneity concerns.

As a useful attribute, this approach also allows to control for observable firm-level heterogeneity by matching firms with high and low debt dependence based on observed characteristics. In the original setting, more and less affected firms differed according to a function of size and age, so matching based on these two or related characteristics was not possible by definition. This is different for the industry-level classification – an advantage that I exploit below.

The measurement approach is conceptually equivalent to those used in the literature (i.e., Duchin *et al.* 2010). It first ranks industries according to the average dependence on external debt financing of all firms active in respective fields. To this end, I calculate firm-level values of debt dependence using the universe of Orbis firms headquartered in any of the eight sample countries from 1999 to 2002. The size of this data allows to generate dependence measures on granular industry levels (4-digit NACE codes). As before, using pre-FSAP information mitigates endogeneity concerns. To reduce the effects of outliers, I use the sum of debt and investments for each firm over the three years prior to the FSAP, winsorized at the one percent level. Based on these values, firm-level external debt dependence is defined as the ratio of the net amount of debt issued to investments. Finally, I consider the average level of debt dependence on the industry level to classify firms in the top half of the distribution as ex-ante dependent on external debt and vice versa.

I augment this approach by creating a matched sample of firms with high and low debt dependence using Coarsened Exact Matching (CEM). The CEM approach creates groups of firms that are very similar regarding a specified set of covariates, namely the firm-level controls deployed in the previous estimations: age, size, tangibility, cash flows, debt ratios, and profitability. For consistency, firms are matched based on the sum of respective variables in the pre-FSAP period 1999-2002, and all potential matching candidates are located in the same country. CEM assigns firms into strata that fall into the same combination of bins of respective variables. I drop all firms in strata without a corresponding matching partner, which reduces the matched sample to 40,477 firm-year observations. Panel A of Table 8 displays summary statistics and shows that the CEM creates a set of firms that shares very similar characteristics: There is no statistically significant difference in means across several observable firm characteristics, in particular, firms in both subgroups are similar in terms of size and age.

- Insert Table 8 here -

Estimation results: I start by repeating the baseline regressions on the effect of the FSAP but exchange the *Constrained* indicator with the dummy variable *Dependence*, which equals one for firms in industries with a high ex-ante dependence on debt financing as defined above and zero otherwise. The results displayed in Panel B of Table 8 confirm that firms, which operate in industries with relatively higher debt dependence, disproportionally respond to financial integration in the banking market compared to firms in other industries. Across specifications, the interaction term FI $\times$ *Dependent* is positive and statistically significant.

In addition, I reestimate different variants of the baseline regressions using the matched sample. Panel C of Table 8 displays the results. Columns I, III, and IV are equivalent to the baseline estimations but, again, use the *Dependence*-dummy to flag more affected firms. The coefficients of the interaction term FI $\times$ *Dependence* are positive and highly significant, implying a disproportionally positive effect of the FSAP on ex-ante debt-dependent firms' use of debt. This finding holds across specifications and for both the de jure and de facto integration measures. Column II is an additional variant of Column I, which essentially compares firms within each matching group by including strata fixed effects. The estimate is positive, highly significant, and also economically meaningful. As such, the coefficient of the interaction term (0.141) suggests a disproportional increase in firms' use of debt in ex-ante debt-dependent industries by 14%.

Columns V-VIII repeat the analyses but use patent filings as the dependent variable. The effects on PPQML regressions explaining firms' patenting activities are positive and statistically significant. Again, the results are comparable but slightly weaker than the baseline estimations (see Table 4). For example, the coefficient in Column VI indicates a disproportional increase of about 17% in patent filings for firms active in industries that are highly dependent on external debt relative to firms in other industries.

The above results confirm previous findings by showing that firms with a higher dependence on debt disproportionally respond to enhanced financial integration in the banking sector. Overall, the positive effects of the FSAP on both financing and subsequent patenting activities apply consistently using the alternative classification approach. Compared to the previous results, the more moderate effects may reflect that the industry-level estimates only indirectly mark financially constrained firms, whereas the baseline regressions use a more direct measure. Deploying the industry-level measure of dependence on external debt financing and conducting matched-sample regressions further reduces concerns that the specific mode of sorting firms into more or less affected groups biases the main results. The results are consistent with the baseline estimations and, thus, emphasize that the degree of financing constraints rather than other firm characteristics, such as size and age, drive the previous findings.

5 On the empirical mechanisms

5.1 Did the FSAP affect firms' patenting intensities?

This section explores potential mechanisms behind the main results by assessing firms' patenting expenditures. Considering expenditures is a practical way to examine patenting activities as they provide a clearer picture of changes in firms' operating strategies compared to analyzing the size of their patent portfolios over time. As such, they comprise more dimensions than simple patent counts. Specifically, they include application, grant, and renewal fees. Hence, patenting expenditures are a function of the portfolio scope as they increase with the patent age and the number of designated jurisdictions where protection is sought.[20]

I start by examining whether the FSAP and the higher use of debt can be linked to changes in firms' patenting investment strategies. Panel A of Table 9 displays statistics on firms' annual patenting expenditures available for a subset of firms obtained from Gill and Heller (2022). Firms' patenting intensity is computed in several ways, using annual expenditures over other accounting variables, such as total assets, total expenditures, operating expenditures, and capital investments (see Table A2 in the Appendix A for more details). The average firm spends about 20,000 Euros on patenting activities each year. This number varies greatly, ranging from zero costs to more than 2.5 million Euros annually. Similarly, the corresponding distributions of patenting ratios are highly skewed, with most firms having relatively low shares.

- Insert Table 9 here -

I analyze whether the FSAP affected firms' patenting expenditures by estimating the baseline specification on a set of patent expenditure ratios. Panel B of Table 9 displays the results. Column I uses firms' total patent expenditure-to-asset ratio as the dependent variable, resembling firms' overall patenting intensity. The DID estimate is positive, highly significant, and economically meaningful in size. The coefficient (0.004) suggests a disproportional increase in the patenting intensity of ex-ante financially constrained firms after the adoption of the FSAP compared to unconstrained firms by about 60% (with 0.006 as the mean dependent variable). I confirm this estimate using a set of expenditure ratios as dependent variables, all of which capture the weight of patent-related expenses to other expense items (Columns II-IV). For example, the estimate in Columns II suggests a relative increase in patent expenditures as a fraction of total expenditures by a factor of 33% (= 0.004/0.012).

Estimates in Columns V and VI provide further details on the relationship of patent expenses to the increased use of debt. Here, I use firms' patenting expenditure-to-debt ratios as

[20] Patenting costs are relevant in this study as they are particularly high in Europe (de la Potterie 2010). Moreover, studying patenting expenses and not R&D expenses is beneficial due to the limited availability of R&D data for relatively small private firms. In the sample, patent expenditure information is available for about 20% of firms, while R&D data is only available for a selection of large firms, constituting about 3% of observations. Figure A4 (Appendix A) illustrates the strong positive relationship between R&D and patent expenditures.

dependent variables. The coefficients on the interaction terms FI $\times Constrained$ are positive but insignificant using bank debt and total debt as denominators for the respective patent expenditure ratio. These results indicate that the increase in patenting expenses (and patenting intensity) is proportional to the increase in debt. In sum, the previous findings show that ex-ante financially constrained firms intensify their patenting activities disproportionally relative to other investment dimensions. At the same time, the raised amount of debt is large enough to cover the additional patenting costs associated with the increase in patenting intensity.

5.2 On the disciplining effects of financial constraints

This subsection investigates the impact of the FSAP on patenting activities in greater depth. Intuitively, the ambiguous baseline effects on the patent quality outcomes may hide meaningful heterogeneous implications of financing constraints for firms' patenting activities. Answering whether financing constraints can also have beneficial effects in disciplining firms is essential for interpreting the findings of this paper from a policy perspective.

To shed light on this question, I distinguish firms with high and low ex-ante patenting activities, which is similar to comparing incumbents and entering firms. Conditional on being ex-ante financially constrained, it is a priori not clear how improved access to debt financing affects the patenting activities of firms with high ex-ante patenting activities (hereafter, incumbents) and firms with little patenting activities (hereafter, entrants). In other words, it is not clear whether the disciplining effect of financing constraints dominates the credit-supply effect and whether this is consistent for incumbents and entrants.

Plausibly, relaxing financing constraints may induce firms to file patents of lower average quality in line with removing a disciplining device. As such, rational firms would first implement projects with the highest expected value if they were restricted in realizing all of the projects among their set of available alternatives (Hottenrott and Peters 2012). Alleviating such restrictions will cause them to work on inventive projects of *relatively* lower quality out of their set of alternatives as long as these projects still have a positive net present value. Such a decline in innovative efficiency can be thought of as decreasing returns to investment in inventive activities (Lokshin *et al.* 2008). This effect could dominate for incumbents if they have already exhausted their pipeline of promising projects. These firms might be closer to reaching the point of diminishing marginal returns as compared to entrants. Yet, this effect may as well be stronger for entrants because they may have been reluctant to patent for a reason. As such, high opportunity costs of patenting typically crowd out firms of relatively low ability, while relaxing financing constraints lowers their opportunity costs to file a patent, even if respective patents are of relatively low quality (see de Rassenfosse 2013).

Similarly, the positive effects of lifting financing constraints for ex-ante constrained firms (i.e., the credit-supply effect) may dominate for incumbents or entrants. Incumbents may be considered high-ability patentees as they actively patent despite their constraints. Hence, they could particularly benefit from improved access to financing if it allows them to deepen their already successful patenting path. Yet, entrants might also disproportionally benefit from relaxed financing constraints because the previously limited access to financing might have dampened patenting activities to a degree that did not allow them to develop a meaningful patenting record. This obstacle could be particularly problematic, for instance, if it mutes spillover effects. Better access to financing may thus strengthen the inventive capabilities of entrants, encouraging them to pursue a more active patenting strategy.

These contradicting considerations demand an empirical assessment to determine whether or not the removal of financing constraints may have unintended adverse effects by lifting a disciplining device for incumbent and entering firms, respectively. To answer this question, I repeat the baseline regressions, which explain the effect of the FSAP on firms' patenting activities but use split samples separating incumbents and entering firms. To be consistent with before, I consider firms' ex-ante patenting intensity based on their ex-ante patenting expenditures: I classify firms as high patenting-intensive (incumbents) once they have above median patenting expenses for the country-specific years in which $FI < 0.2$, and vice versa.

I start by examining the differential effects of the FSAP on patent filings. Figure 3 plots the event-study type regression estimates on the effect of the FSAP for financially constrained firms, similar to Figure 2. Only here are the effects displayed separately depending on firms' ex-ante patenting intensities. Panel A displays results for regressions that use the number of patents filed as the dependent variable. In both subsamples, firms gradually increase the number of patent filings over time, with the estimated coefficients following a similar path. Hence, ex-ante patenting intensities do not explain differences in firms' responsiveness to improved access to external debt financing regarding the patent *quantity*.

- Insert Figure 3 here -

Next, I turn to patent quality-related outcomes. Panel B of Figure 3 summarizes the differential effects of the FSAP for financially constrained firms with high and low ex-ante patenting intensities graphically. The effects are similar along some dimensions, such as the market value patenting dimensions. Yet, the estimates also suggest that the favorable effects on patent quality in the baseline estimates are driven by entering firms, while incumbents drive the adverse effects. More specifically, entering firms exhibit a disproportionally positive effect on forward citations and high-impact patents, suggesting an enhancing effect of improving access to external financing for firms with little prior patenting activities. This finding aligns with the "credit-supply" effect of removing financing constraints. In contrast, for the subsample of incumbent firms, the coefficients on incremental patents (positive) and technological diversity (negative) are statistically significant. This result supports the hypothesis that financial constraints serve as a disciplining device for incumbent firms before the treatment, corroborating the notion of the patent paradox (e.g., Hall and Ziedonis 2001).

In sum, these analyses uncover two main insights on the implications of the FSAP. First, conditional on being financially constrained, the improved access to finance induced these firms to file more patents irrespective of their ex-ante patenting intensity. Second, studying patent quality dimensions suggests that relaxing financing constraints has beneficiary outcomes regarding the quantity and quality of patenting activities for entering firms with low ex-ante patenting intensities while having rather adverse effects on the quality of patents filed by incumbent firms. These findings are important from a policy perspective, as they disclose contrasting insights on government-induced improvements in access to financing.[21]

6 Conclusion

This paper examines one of the most considerable policy efforts in the EU to integrate financial markets across member states, the Financial Services Action Plan, and its impact on firms' financing and subsequent inventive activities. Investigating the implications of policy-induced improvements in firms' access to external financing is crucial since financial resources are viewed as a key determinant of innovative activities and, thus, economic growth. Consistent with this perspective, many policy initiatives aim to improve access to finance, particularly for more vulnerable, financially constrained firms. At the same time, there is evidence of the adverse effects of relaxing financing constraints on firms' inventive efficiency. In particular, prior research has identified a potential quantity-quality tradeoff in the context of patenting. This study aims to improve our understanding of the ex-ante ambiguous (and potentially unintended) implications of financing-related policy initiatives on firms' inventive activities.

The empirical analyses provide a nuanced picture of the effects of the FSAP, using a large-scale sample of primarily small and medium-sized firms across multiple European countries and industries. First, the FSAP caused previously financially constrained firms to raise their use of debt to a statistically and economically significant degree. As a likely channel, the changes in law fostered debt financing by lowering its costs. Second, firms that benefited from the legal amendments *subsequently* filed for more patents. Estimates suggest that moving the average firm from the pre- to the post-integration periods raises the likelihood of filing a patent by 25%. Third, the increase in patent filings is, on average, not accompanied by changes in patent quality. Hence, the average firm that benefits from better access to debt financing does not file patents of worse quality per se. Fourth, distinguishing ex-ante financially constrained firms according to their pre-integration patenting intensity shows that previously low patenting-intensive firms

[21] I acknowledge that this discussion must be evaluated cautiously because the differences in the coefficients across high and low ex-ante patenting-intensive firms are relatively small. Evaluating causal effects along this angle may be a promising avenue for future work.

raise both the quantity and the quality of patent output. In contrast, there is a moderate quantity-quality tradeoff for firms with high pre-integration patenting intensity, i.e., those firms file more incremental and less technologically diverse patents.

These results have important policy implications. As such, they emphasize the relevance of access to finance for inventive activities, especially for financially constrained firms. Firms benefit from more integrated financial markets by improved financing conditions and alleviating financial constraints, which helps spur firms' patenting activities. However, heterogeneity in the results shows that the impact of financing constraints on inventive activities is more complex than the narratives of most policy initiatives suggest. In particular, the results suggest caution about governmental and managerial policies that primarily target monetary aspects to enhance research activities as they may entail (unintended) adverse effects. Different outcomes regarding the quantity and quality of patents further highlight the importance of acknowledging both dimensions when evaluating the efficient allocation of research funding.

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Tables from the main part:

Table 1: Sample descriptives: firm-level data

Panel A: Distribution of observations, firms, and patent counts across countries

	Sample						Actual distributions	
Country	Obs.	(in %)	Firms	(in %)	Patents	(in %)	Firms (%)	Patents (%)
Belgium	7,797	(6.57)	1,318	(5.95)	30,480	(4.33)	(3.67)	(2.84)
Finland	9,972	(8.40)	1,711	(7.72)	27,700	(3.94)	(1.97)	(3.36)
France	40,680	(34.26)	6,542	(29.52)	219,118	(31.15)	(18.79)	(15.61)
Germany	16,188	(13.63)	4,987	(22.50)	224,959	(31.98)	(20.92)	(43.23)
Italy	1,260	(1.06)	202	(0.91)	1,847	(0.26)	(28.53)	(7.10)
Netherlands	2,785	(2.35)	560	(2.53)	33,255	(4.73)	(6.45)	(9.33)
Sweden	16,271	(13.70)	2,644	(11.93)	72,773	(10.35)	(4.48)	(5.62)
United Kingdom	23,771	(20.02)	4,197	(18.94)	93,246	(13.26)	(15.19)	(12.90)
Total	118,724	(100.00)	22,161	(100.00)	703,378	(100.00)	(100.00)	(100.00)

Panel B: Descriptive statistics on firm-level data

Variable	**Obs.**	**Mean**	**SD**	**Q25**	**Q50**	**Q75**
Firm size	118,724	8.831	2.518	7.124	8.855	10.495
Tangibility	118,724	0.204	0.210	0.048	0.135	0.294
Cash-flow ratio	118,724	0.065	0.188	0.028	0.086	0.146
Profitability (RoA)	118,724	0.061	0.138	0.003	0.048	0.111
Bank debt (log.)	118,724	6.778	2.999	4.997	7.097	8.839
Bank loan ratio	118,724	0.237	0.207	0.085	0.180	0.337
Listed	118,724	0.050	0.219	0	0	0
Firm age	118,465	25.45	26.47	9	17	33
# Employees	96,105	1,576	13,707	13	65	256

Notes: Panel A displays the distribution of firm-year observations in the main sample across sample countries, including the corresponding numbers of firms and patents. Parentheses next to respective values indicate the shares as fractions of column totals. The last two columns display the actual distributions of the number of firms and patents filed in respective sample countries, with the reference years 2008, i.e., the earliest year in which respective data was available for all sample countries. The percentages reflect the share of firms and patents from respective countries as a fraction of the total firms and patents from all sample countries. The source for the number of firms is Eurostat, Table: BD_9BD_SZ_CL_R2 (Population of active enterprises - Total). The source for patent applications is the WIPO statistical database; filings refer to the total patent applications (direct and PCT national phase entries), which is comparable to the data in this sample. Panel B displays summary statistics on firm financial information from ORBIS. The first four variables are the set of controls denoted as "firm-level" controls, included in most regressions. Table A2 (Appendix A) contains detailed definitions of all variables used in this analysis.

Table 2: Overview and definitions of patenting dimensions

Category	Name	Definition	Obs.	Mean	SD	Min.	Max.
Quantity	Patent filings	Total number of patent applications within a year	118,724	5.924	46.388	0	2,987
Quality	Forward citations	Citations received within the first seven years after filing	56,727	1.632	4.036	0	204
	Claims	Number of claims as fraction of referenced patents	56,727	0.420	1.169	0	63
Value	Family size	Number of (EPC) jurisdiction in which a patent is active	56,727	4.005	3.140	1	36
	Renewals	Ex-post measured number of patent renewals (starting with the third year after filing)	56,727	0.486	1.339	0	18
Patent types	Incremental	Both criteria have to be fulfilled: i) Not a high-impact patent (a) ii) Not a high scope patent (b)	56,727	0.448	0.206	0	1
	Explorative	Both criteria have to be fulfilled: i) High-impact patent (a) ii) High scope patent (b)	56,727	0.018	0.097	0	1
	High-impact (a)	Classification criteria: 1) > 0 forward citations (cits) 2) > avg. forward-backward cits ratio 3) > avg. claims-backward cits ratio 4) > 80% A-type references	56,727	0.056	0.170	0	1
	Technological diverse (b)	Classification criteria: 1) > avg. patent scope 2) > avg. patent originality	56,727	0.270	0.373	0	1

Notes: The table lists variable definitions and descriptive statistics on the different patenting dimensions. All patenting variables are computed at the firm-year level, measuring the average values of all patents filed by a firm in a given year. The quality-related measures are missing for any year in which the respective firms did not file patents. Appendix B elaborates on the computation and definitions of the patenting variables in detail.

Table 3: Financial integration and debt financing

Panel A: Baseline regression results: the effect of the FSAP on firms' use of debt

Dependent variable:	Bank debt (log.)			
	(I)	(II)	(III)	(IV)
FI × *Constrained*	0.237***	0.118***	0.193***	0.203***
	(0.032)	(0.027)	(0.053)	(0.030)
Constrained	-0.170***			
	(0.029)			
FI	0.864***			
	(0.071)			
FI definition:	de jure	de jure	de facto	de jure
Additional controls:				
Firm level	Yes	Yes	Yes	No
Macro level	Yes	No	No	No
Industry FE	Yes	No	No	No
Firm FE	No	Yes	Yes	Yes
Country-Year FE	No	Yes	Yes	Yes
R^2	0.69	0.90	0.90	0.89
Observations	115,906	115,906	115,906	115,906

Panel B: The FSAP, interest burden, and related changes in bank debt

Dependent variables:	Interest burden		Bank debt (log.)			
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × *Constrained*	-0.007***	-0.005**	0.148***	0.037	0.066	0.006
	(0.003)	(0.002)	(0.042)	(0.045)	(0.049)	(0.040)
Constrained	-0.023***				-0.173***	
	(0.003)				(0.042)	
FI	0.016***				0.273***	
	(0.002)				(0.064)	
Beneficiary					-0.066**	
					(0.032)	
Beneficiary × *Constrained*					-0.039	
					(0.058)	
FI × Beneficiary					0.042	
					(0.035)	
FI × Beneficiary × *Constrained*					0.151**	0.162***
					(0.067)	(0.053)
Firms' interest burden	All	All	Improved	Worsen	All	All
Additional controls:						
Firm level	Yes	Yes	Yes	Yes	Yes	Yes
Macro level	Yes	No	No	No	Yes	No
Industry FE	Yes	No	No	No	Yes	No
Firm FE	No	Yes	Yes	Yes	No	Yes
Country-Year FE	No	Yes	Yes	Yes	No	Yes
R^2	0.05	0.58	0.88	0.87	0.71	0.87
Observations	63,705	63,705	44,643	35,592	80,235	80,235

Notes: Panel A presents the DID coefficient estimates from fixed effects panel regressions explaining the effect of financial integration on the use of bank loans. The regressions are different variants of the baseline specification, as defined in Equation (2), using the logarithm of bank loans as dependent variable. Column I is similar to the baseline specification but includes industry fixed effects and country-level macroeconomic controls instead of firm- and year fixed effects, such that it is possible to estimate the base-coefficients. Column II estimates the baseline specification. In Column III, the FI-variable is the *de facto* measure of financial integration as defined in Section 2.2. Column IV is similar to the baseline specification in Column II but time-variant co-variates (i.e., firm level controls) are omitted to account for issues associated with DID estimations as proposed by Sant'Anna and Zhao (2020). Panel B presents estimates on the impact of financial integration on firms' interest burden. Columns I and II repeat the first two columns from Panel A but use firms' interest burden as dependent variable. Columns III and IV display estimates on the baseline specification using the logarithm of bank debt as dependent variable, only here the regressions are estimated on split samples. Estimations include firms that face lower interest burdens comparing post- to pre-treatment periods and those facing the same or relatively higher interest burdens, respectively. Columns V and VI use the full sample and estimate the baseline regression but add a triple interaction of the DID estimator (Equation 2) multiplied with an indicator on whether a firm faces a lower interest burden comparing post- to pre-treatment periods (i.e., $Beneficiary$). 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 levels, respectively.

Table 4: Baseline regression results: Financial integration and patenting activities

Panel A: The effect of the FSAP on firms' patent filings

Dependent variable:	Patent filings				
	(I)	(II)	(III)	(IV)	(V)
FI × *Constrained*		0.176***	0.224***	0.344***	0.160***
		(0.048)	(0.047)	(0.079)	(0.033)
Constrained		0.344***			
		(0.050)			
FI	-0.078	-0.212**			
	(0.086)	(0.088)			
FI definition:	de jure	de jure	de jure	de facto	de jure
Additional controls:					
Firm level	Yes	Yes	Yes	Yes	No
Macro level	Yes	Yes	No	No	No
Industry FE	Yes	Yes	No	No	No
Firm FE	No	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes	Yes
Pseudo R^2	0.28	0.29	0.73	0.73	0.73
Observations	115,906	115,906	115,906	115,906	115,906

Panel B: The effect of the FSAP on qualitative dimensions of patenting

Patenting dimensions:	Technological quality		Market value		Patent types			
Dependent variables:	Forward citations	Claims	Family size	Renewals	Incremental	Explorative	High impact	Technological diverse
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × *Constrained*	0.240**	0.007	-0.246**	-0.126***	0.001	0.002	0.010*	-0.021*
	(0.120)	(0.040)	(0.096)	(0.034)	(0.006)	(0.003)	(0.005)	(0.012)
Additional controls:								
Firm level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.42	0.37	0.73	0.42	0.51	0.32	0.33	0.50
Observations	46,937	46,937	46,937	46,937	46,937	46,937	46,937	46,937

Notes: Panel A presents estimates from panel regressions explaining the effect of the FSAP on the number of firms' annual patent filings using Poisson pseudo quasi-maximum likelihood regressions with multiple levels of fixed effects. Column I regresses the *de jure* FSAP measure as defined in Equation (1) and a set of control variables on patent filings. Columns II-V are specified as in Columns I-IV of Panel A in Table 3; only here, the dependent variable is patent filings. Hence, Column III displays the baseline results estimating Equation (2). Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. Panel B presents the estimates using this baseline specification, only here estimates are from panel regressions explaining the effect of the FSAP on the full set of patent quality-related measures as introduced in Section 3.2. Standard errors in both panels (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 5: Firm-level heterogeneity and the effect of financial market integration

Panel A: RZ score and the effects of the FSAP

Dependent variable:	Bank debt (log.)			Patent filings		
Dependence on external financing ($RZscore^{\mathrm{high}}$):	Low	High	All	Low	High	All
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × *Constrained*	0.022	0.152***	0.039	0.095	0.329***	0.091
	(0.039)	(0.039)	(0.039)	(0.074)	(0.064)	(0.073)
FI × $RZscore^{\mathrm{high}}$			0.019			-0.114*
			(0.030)			(0.068)
FI × *Constrained* × $RZscore^{\mathrm{high}}$			0.110**			0.231**
			(0.055)			(0.097)
Additional controls:						
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
Observations	54,672	54,685	109,357	54,672	54,685	109,357

Panel B: The FSAP and high-growth firms as alternative explanation for the main effects

Dependent variable:	Bank debt (log.)			Patent filings		
$\mathrm{Growth}^{\mathrm{high}}$ definition:	Assets	Employment	Staffing costs	Assets	Employment	Staffing costs
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × $\mathrm{Growth}^{\mathrm{high}}$	0.000	0.045	0.054*	0.025	0.049	-0.037
	(0.030)	(0.030)	(0.029)	(0.030)	(0.031)	(0.030)
FI × *Constrained*	0.117***	0.085**	0.109***	0.213***	0.248***	0.230***
	(0.033)	(0.036)	(0.034)	(0.029)	(0.031)	(0.030)
Additional controls:						
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
Observations	66,069	53,494	62,473	66,069	53,494	62,473

Notes: The tables present regressions that explain firms' use of debt and patent filing activities, distinguishing among firms' ex-ante financing and growth patterns. The dependent variables in both panels are the logarithm of bank debt (Columns I-III) and patent filings (Columns IV-VI). Panel A analyzes the role of firms' ex-ante demand for external financing, approximated using the RZ score as defined in Table A2 (Appendix A). Columns I-II repeat the baseline regression for a subsample of firms with low and high dependence on external finance. Column III adds interactions of $RZscore^{\mathrm{high}}$ with the main interaction term, FI × *Constrained*. $RZscore^{\mathrm{high}}$ is a dummy variable equal to one for all firms with high ex-ante $RZscore$ and zero otherwise. The base variable and the interaction of $RZscore \times Constrained$ are omitted due to perfect multicollinearity. Columns IV-VI repeat the first three specifications but use patent filings as dependent variable. In Panel B, regressions are similar to the baseline specification but add an interaction term of $FI \times \mathrm{Growth}^{\mathrm{high}}$; $\mathrm{Growth}^{\mathrm{high}}$ is a dummy equal to one for firms that exhibit above median levels of growth during the pre-treatment period. Growth is defined as the year-over-year growth in total assets (Column I), total employment (Column II), and expenses on employees' wages (Column III). Again, Columns IV-VI repeat the first three specifications but use patent filings as dependent variable. 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 levels, respectively.

Table 6: Testing the robustness to the timing of the FSAP adoption

Panel A: Re-estimating main specification using "clean" controls

Dependent variable:	Bank debt (log.)				Patent filings			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × *Constrained*	0.239***	0.083***	0.109***	0.190***	0.227***	0.301***	0.237***	0.196***
	(0.057)	(0.029)	(0.031)	(0.033)	(0.063)	(0.074)	(0.080)	(0.051)
Mean dep. var.:	7.755	6.857	6.867	7.266	5.738	3.989	3.956	4.717
Sample (adopters):	Early	Late	Late (no lagged)	No lagged	Early	Late	Late (no lagged)	No lagged
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(Pseudo) R^2	0.84	0.95	0.95	0.88	0.75	0.71	0.71	0.74
Observations	50,028	57,502	49,838	92,202	50,028	57,502	49,838	92,202

Panel B: Average treatment effects on the treated using Callaway and Sant'Anna (2021)

Dependent variable:	Bank debt (log.)				Patent filings			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × *Constrained*	0.131***	0.127***	0.066**	0.047*	0.280	0.230	0.310**	0.290**
	(0.037)	(0.031)	(0.027)	(0.026)	(0.203)	(0.147)	(0.132)	(0.121)
First treatment year (FI>):	0.0	0.15	0.40	0.50	0.0	0.15	0.40	0.50
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	74,378	89,236	91,439	96,871	74,378	89,236	91,439	96,871

Notes: The tables present analyses of the main estimations' robustness regarding the staggered implementation of the FSAP Directives across sample countries. Panel A presents an approach to exclude "not-clean" controls, i.e., firms from countries with different implementation structures of the FSAP. Estimates are obtained using different subsamples of countries and explain firms' financing (Columns I-IV) and patenting activities (Columns V-VIII). The underlying regression specifications are equivalent to the main specifications (Columns II of Table 3 and Column III of Table 4. In Columns I and V, the subsample is all "early" adopting countries that implemented the first FSAP Directive in 2002: Germany, Great Britain, Italy, the Netherlands, and Sweden. Conversely, Columns II and VI include all "late" adopting countries: Belgium, Finland, and France. Columns III and VII are similar to before but exclude Belgium as it lags adoption of the FSAP in 2003. Columns IV and VIII use firms from all countries but the two lagging countries, Belgium and Sweden. See Figure A1 Panel B in Appendix A for details on the variation of the de jure integration measure over time. Panel B deploys the Callaway and Sant'Anna (2021) method as a standard approach of controlling for "non-clean" controls, using the *csdid* command in Stata. This estimation method requires predefining an initial "treatment" year. To acknowledge that financial integration resembles a continuous treatment without such a specific cutoff, a set of different treatment years is chosen in which the de jure integration measure exceeds 0.0, 0.15, 0.40, or 0.50, respectively. Other than this, there is no difference in the regression specification: Columns I-IV and V-VIII use the log of total debt and patent filings as main dependent variables, respectively, gvar equals the calendar years, and ivar equals the firm-id. Variation in the number of observations arises from the csdid command, which automatically omits observations without pair balance (i.e., not observed in t-1 and t0). Standard errors in all panels (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 7: Placebo regressions: analysis on the Euro introduction in 1999

Dep. variables:	Bank debt (log.)					Patent filings	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
$FI^{\text{placebo}} \times$ *Constrained*	0.076*	-0.025	0.033	0.030	0.054	0.085	0.060
	(0.041	(0.035)	(0.031)	(0.049)	(0.037)	(0.057)	(0.052)
FI^{placebo}	0.389***					0.269***	
	(0.041)					(0.081)	
Treat	-0.131***					-0.216***	
	(0.041)					(0.056)	
Sample countries:	Euro	Euro	All	Euro	All	Euro	Euro
Treatment variable:	Binary	Binary	Binary	Mimic FI	Mimic FI	Binary	Binary
Additional controls:							
Firm level	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro level	Yes	No	No	No	No	Yes	No
Industry-FE	Yes	No	No	No	No	Yes	No
Firm-FE	No	Yes	Yes	Yes	Yes	No	Yes
Country-Year-FE	No	Yes	Yes	Yes	Yes	No	Yes
Observations	27,695	27,695	44,185	27,695	44,185	16,250	16,250

Notes: This table presents estimates from panel regressions using the introduction of the Euro as a potential alternative treatment event for explaining the effect of financial integration on firms' financing and patenting activities. Regressions are similar to the baseline estimations but use a time window around the alternative treatment between 1997-2004. In Columns I-V, the dependent variable is the logarithm of bank debt. The variable FI^{placebo} measures the adoption of the Euro; In Columns I-III, FI^{placebo} is equal to one for all years after 1999 and zero otherwise. Columns IV and V use a continuous treatment variable similar to 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. The sample in Columns I, II, and IV are all countries from the original setting. The sample in Columns III and V excludes Denmark, Great Britain, and Sweden, i.e., only includes the Eurozone countries from the original sample. Columns VI and VII repeat the first two columns but use the number of patents filed as dependent variable. 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 levels, respectively.

Table 8: Matched sample regressions

Panel A: Summary statistics of the matched sample by groups

Variable	***Dependent* = 1** Mean	SD	***Dependent* = 0** Mean	SD	**Differences in means**	(*p-value*)
Firm age	20.64	18.56	20.78	17.90	-0.146	(*0.274*)
Firm size	8.757	2.537	8.672	2.417	0.085	(*1.179*)
Tangibility	0.219	0.212	0.227	0.208	-0.008	(*1.344*)
Cash-flow ratio	0.096	0.136	0.098	0.128	-0.002	(*0.438*)
Profitability (RoA)	0.064	0.094	0.063	0.088	0.001	(*0.511*)
Bank debt (log.)	7.103	2.742	7.001	2.656	0.102	(*1.291*)
Bank loan ratio	0.268	0.181	0.267	0.189	0.001	(*0.172*)
Patent filings	3.487	9.629	3.105	8.371	0.382	(*1.440*)

Panel B: Re-estimating baseline regressions using the full sample

Dependent variable:	Bank loans			Patent filings		
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × *Dependent*	0.097***	0.055**	0.096**	0.091*	0.176***	0.272***
	(0.039)	(0.039)	(0.039)	(0.052)	(0.051)	(0.073)
Dependent	0.894***			-0.154*		
	(0.055)			(0.093)		
FI	-0.071**			0.065		
	(0.030)			(0.051)		
FI definition:	de jure	de jure	de facto	de jure	de jure	de facto
Additional controls:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Macro-level	Yes	No	No	Yes	No	No
Industry FE	Yes	No	No	Yes	No	No
Firm FE	No	Yes	Yes	No	Yes	Yes
Country-Year FE	No	Yes	Yes	No	Yes	Yes
Observations	115,906	115,906	115,906	115,906	115,906	115,906

(*continued on next page*)

Table 8: *continued*

Panel C: Re-estimating baseline regressions using the matched sample

Dependent variable:	Bank debt (log.)				Patent filings			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × *Dependent*	0.157***	0.141***	0.114***	0.202***	0.164**	0.160**	0.168**	0.243**
	(0.045)	(0.034)	(0.033)	(0.056)	(0.083)	(0.074)	(0.073)	(0.120)
Dependent	0.245***	0.031**			0.141	-0.026		
	(0.075)	(0.018)			(0.089)	(0.032)		
FI	-0.034	-0.159***			0.039	0.268***		
	(0.182)	(0.040)			(0.227)	(0.089)		
FI definition:	de jure	de jure	de jure	de facto	de jure	de jure	de jure	de facto
Additional controls:								
Macro-level	Yes	Yes	No	No	Yes	Yes	No	No
Industry FE	Yes	No	No	No	Yes	No	No	No
Strata FE	No	Yes	No	No	No	Yes	No	No
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Country-Year FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	42,573	42,573	42,573	42,573	42,573	42,573	42,573	42,573

Notes: The tables present summary statistics and corresponding regressions using the alternative classification of firms with a high and low propensity to respond to integration in the banking market. The definition of more or less affected firms distinguishes firms that are active in industries with a relatively high ($Dependent = 1$) or low ($Dependent = 0$) dependence on debt financing. Panel A presents summary statistics for these two firm categories in the matched sample, including the differences in means between the two groups and the corresponding p-values in the last two columns. Panel B re-estimates the baseline specification deploying the classification to the baseline estimates. Columns I-III are equivalent to Columns I-III of Table3 and Columns IV-VI are equivalent to Columns II-IV of Table 4, only here the dummy indicating the affectedness to the financial integration process is *Dependent* instead of *Constrained*. Panel C repeats the baseline regressions that explain the effect of the FSAP on debt financing and patenting activities of firms using the matched sample and the industry-level ex-ante dependence on external debt financing classification to distinguish firms that are relatively more or less exposed to the financial integration process. The specifications are similar to those in Panel B; only Column II is different: here, matched-group fixed effects (Strata FE) are included instead of industry fixed effects like in Column I. Columns V-VIII repeat the first four specifications but use patent filings as the dependent variable. In Panels B and C, 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 levels, respectively.

Table 9: Financial integration and patenting expenditures

Panel A: Summary statistics on expenditure variables

Variable	Obs.	Mean	SD	Min.	Max.
$PatExp$	18,911	19,775	97,748	0	2,512,505
$PatExp$-to-assets	18,911	0.006	0.024	0	0.179
$PatExp$-to-expenses	16,809	0.012	0.058	0	0.459
$PatExp$-to-opex	9,180	0.009	0.027	0	0.349
$PatExp$-to-capex	8,053	0.021	0.094	0	0.711
$PatExp$-to-total-debt	16,843	0.028	0.134	0	1.090
$PatExp$-to-bank-debt	18,220	0.053	0.250	0	2.026

Panel B: Regression estimates explaining changes in patent expenditure ratios

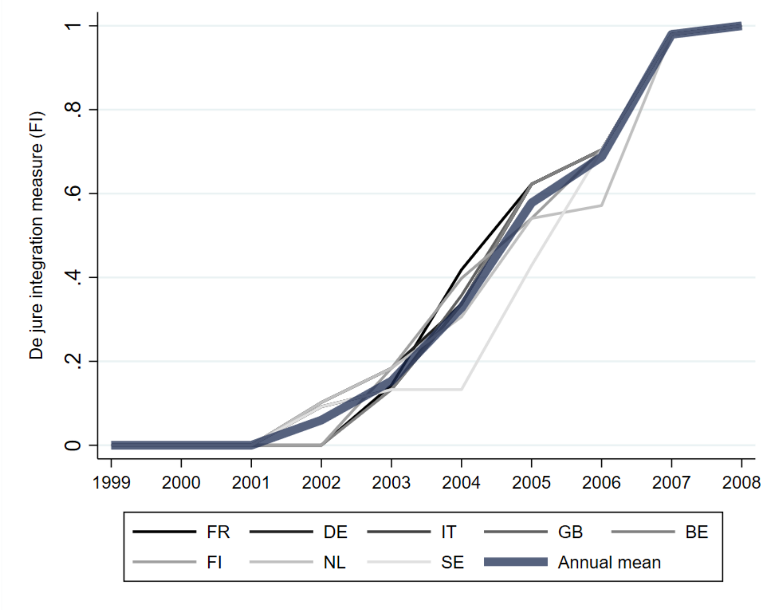
Dependent variable:	Patenting expenditures ratios					
Denominator:	Assets	Total expenses	Opex	Capex	Total debt	Bank debt
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × *Constrained*	0.004***	0.004**	0.006***	0.011*	0.008	0.017
	(0.001)	(0.003)	(0.003)	(0.007)	(0.007)	(0.013)
Additional controls:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.83	0.76	0.81	0.75	0.76	0.74
Observations	18,593	18,288	9,001	7,827	16,506	17,878

Notes: Panel A displays summary statistics on different variants of the patent expenditure ratios as defined in Table A2 (Appendix A). Panel B presents OLS estimates from fixed effects panel regressions estimating the effect of the FSAP on respective ratios. The regressions are equivalent to the baseline specification but use the six expenditure ratios from Panel A as dependent variable. 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 levels, respectively.

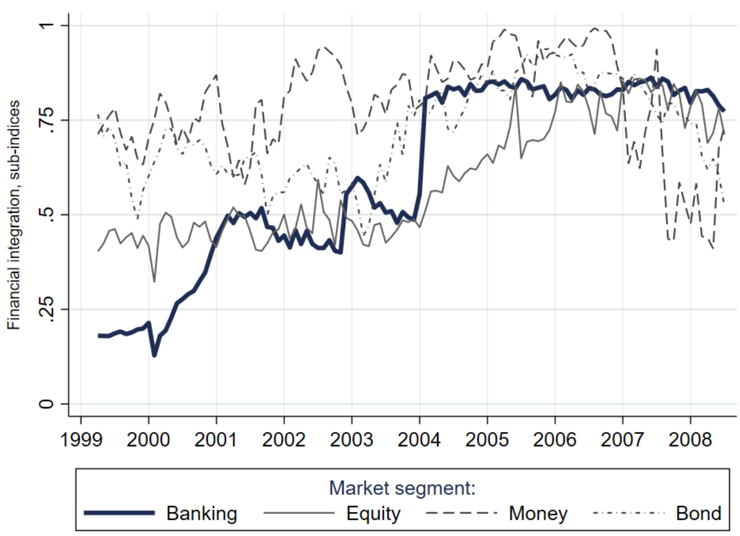
Figures from the main part:

Figure 1: Measuring financial market integration

Panel A: De jure integration measure based on FSAP Directives (1999-2008)



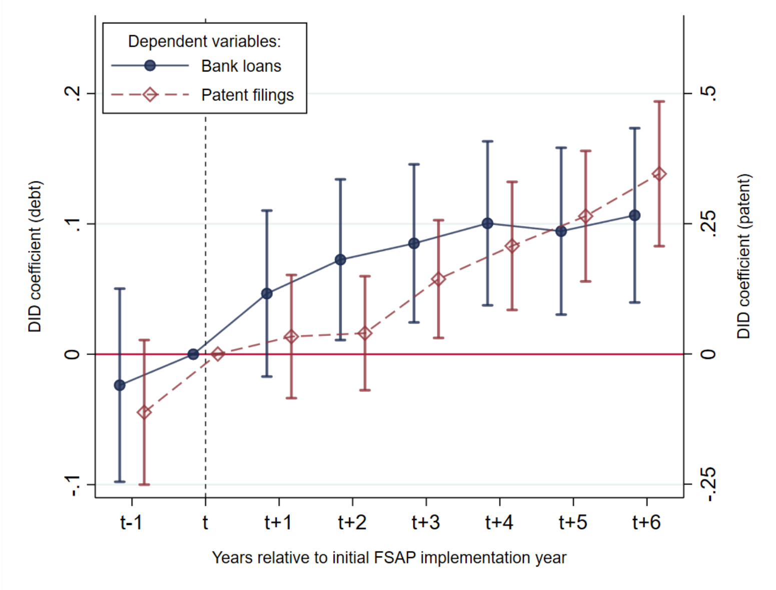
Panel B: De facto integration measure



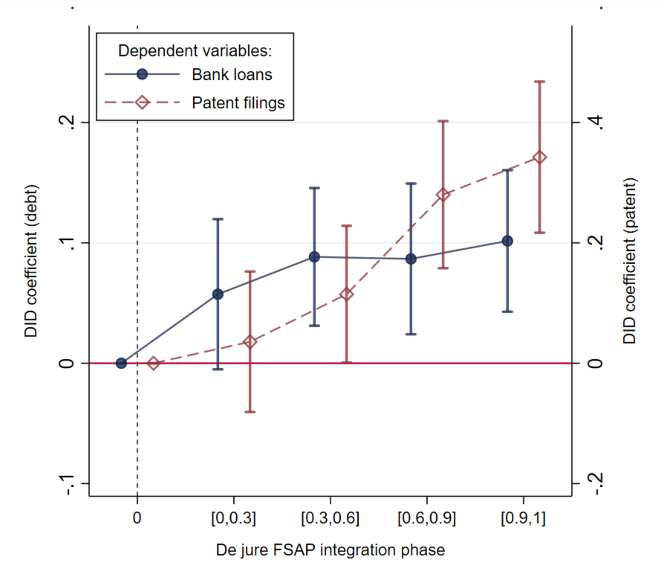
Notes: These graphs plot the two main measures of financial market integration over the sample time frame. Panel A displays the *de jure* integration measure, FI, as defined in Equation (1). Each thin line represents one sample country, and the thick line plots the average FI value per year. Figure A1 (Appendix A) contains more details on the specific values. The de jure measure of integration in the European banking sector indicates low (= 0) and high (= 1) multilateral adoption of FSAP Directives. Panel B displays the *de facto* integration measure using a price-based measure obtained from Hoffmann *et al.* (2020). The figure plots integration variables of the four main market segments: money markets, bond markets, equity markets, and banking markets. The banking market indicator is the bold solid line.

Figure 2: Event-study type regression: The timing of the baseline effects on firms' use of bank debt and patenting activities

Panel A: DID coefficients in years relative to the initiation of the FSAP



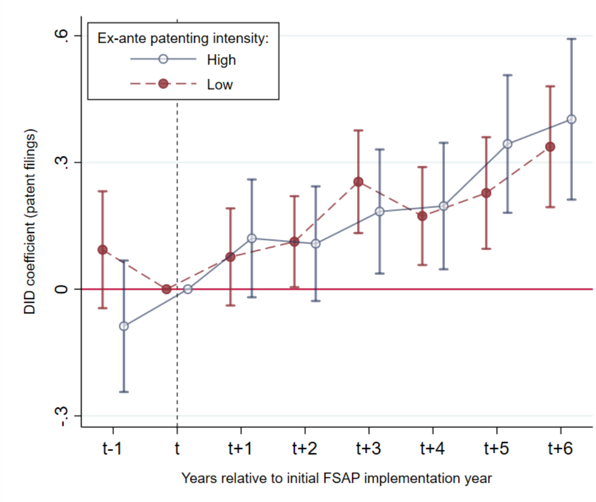
Panel B: DID coefficients for different FSAP phases



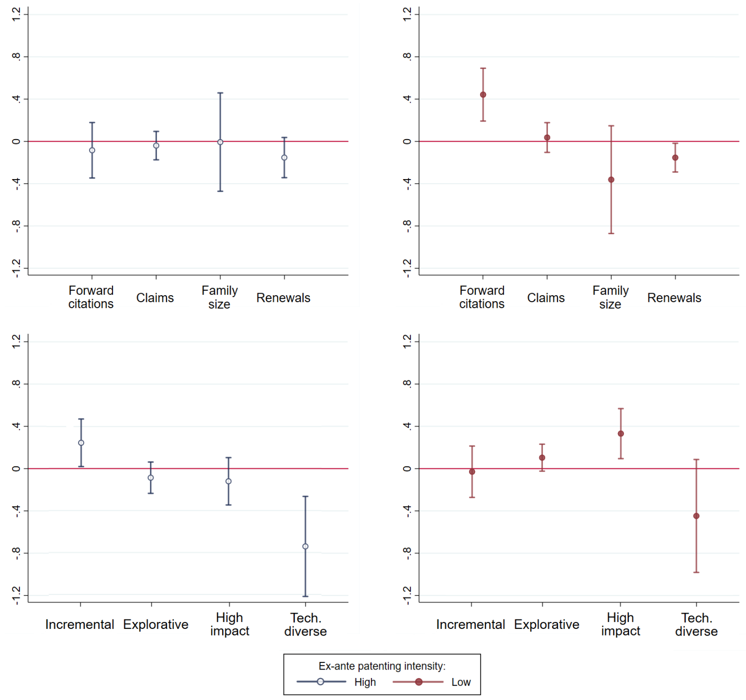
Notes: The figures display estimates on event-study type regressions, decomposing the baseline effect across time. The estimation specification is defined in Equation (3). In Panel A, the periods refer to the calendar years relative to the country-specific last year in which none of the FSAP Directives was adopted ($FI = 0$). The corresponding average FI values for the years t-1 until t+6, as defined in Equation (eq:fintegration), are: 0.00, 0.00, 0.12, 0.29, 0.46, 0.66, 0.84, and 0.99, respectively. Panel B distinguishes among five integration phases: pre-FSAP, the early phase, the intermediate phase, the late phase, and the fully integrated phase; the corresponding FI values are displayed on the horizontal axis labels of the chart. Here, the pre-FSAP phase is used as reference period. Whiskers span the 90 percent confidence intervals.

Figure 3: Heterogeneous effects across split samples: high and low ex-ante patenting intensities

Panel A: DID baseline coefficient for firms with high and low ex-ante patenting intensities



Panel B: DID coefficients on patent quality and patent types for split sample



Notes: Panel A is identical to Panel A of Figure 2 and resembles the event-study type baseline regression explaining the effect of the FSAP on the patenting activities of financially constrained firms. Again, the dependent variable is the annual number of patent filings. Only here, the regression is estimated separately for firms with high and low patenting intensities. Patenting-intensive firms have an above-median level of patent expenditures in the years before the transposition of FSAP Directives. Panel B plots the DID coefficients as displayed in Panel B of Table 4, but the sample is again split into firms with high and low ex-ante patenting intensities. In both panels, whiskers span the 90 percent confidence intervals.

For online publication only (Appendices):

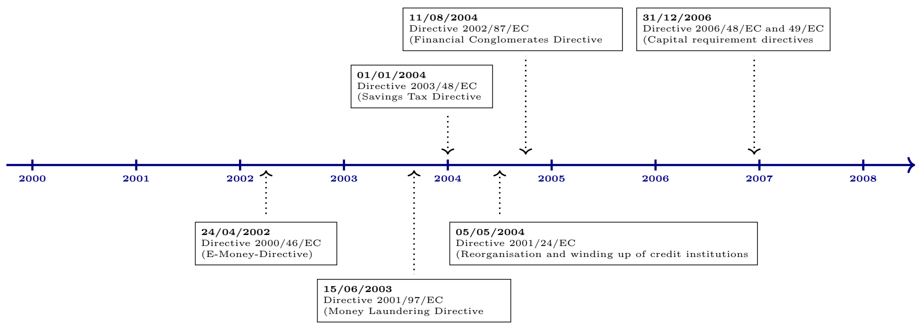
Appendix A : Tables and Figures of the Appendix

Table A1: Financial Services Action Plan: Main amendments and time schedule

Panel A: List of Directives

Directive	Name	Deadline 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

Panel B: Time schedule of the stipulated transposition deadlines



Notes: Panel A lists the 27 Directives of the Financial Services Action Plan, issued by the European Commission on May 11, 1999. Directives marked with * are banking-related FSAP measures as identified by Malcolm *et al.* (2009). Deadline dates refer to the intended transposition date stipulated by the European Commission, i.e., not the actual implementation date, which are country-specific and may vary on a country-by-country basis. The country-specific implementation dates are not reported but can be provided by the author upon request. Panel B illustrates the anticipated timeline of the banking-related FSAP measures graphically.

Table A2: List of variables

Main regressors:	
FI	Measure of financial integration in the banking market; unless specified otherwise the *de jure* measure as defined in Equation (1) is used. If denoted as *de facto* (in the bottom of regression tables), the banking-sector subindex from Hoffmann *et al.* (2020) is used as measure of actual financial market integration. Figure A1 (Appendix A) lists respective values.
Constrained	Dummy equal to one for firms with above median S&A score as defined in Hadlock and Pierce (2010) during the pre-treatment period, i.e., all years in which $FI = 0$, and zero otherwise; in the analyses, firms with $Treat = 1$ and $Treat = 0$ are called "exposed" and "control" firms, respectively.
Beneficiary	Dummy equal to one for firms with lower average interest burden in years $FI > 0.2$ compared to the average for all previous years; zero otherwise.
$\text{FI}^{\text{placebo}}$	Placebo integration variable; monotonic shift of the FI-variable by five years such that the measure is on average > 0.5 as of 1999.
$RZscore^{\text{high}}$	Dummy equal to one for firms with above median RZ values as defined in Rajan and Zingales (1998) during the pre-treatment period, i.e., all years in which $FI = 0$, and zero otherwise.
$\text{Growth}^{\text{high}}$	Dummy equal to one for firms with above median growth in terms of total assets (Orbis, `toas`), total employment (`empl`), or total employment expenditures (`exp_staf`) measured in years $FI < 0.2$, and zero otherwise.
Dependent	Dummy equal to one for firms active in industries with above median dependence on external debt during the pre-treatment period, and zero otherwise; The measure is defined similar to the equity dependence measure in Duchin *et al.* (2010) but uses total debt instead of total equity. First, firm-level dependence on debt is calculated dividing total year-over-year changes in net debt ((`ltdb`,(`cred`, and (`loan`) by changes in assets ($\texttt{toas}_t$ - $\texttt{toas}_{t-1}$) for all firms in the sample countries using the years 1999-2002 from the Orbis database. Respective values are aggregated on the 4-digit NACE level. Based on this distribution, firms are active in the top or bottom half of the distribution are classified as debt dependent or not, respectively.
Firm-level variables (Orbis code):	
Bank debt (log.)	Logarithm of total bank debt outstanding at the end of the year (`loan` plus `cred`).
Bank loan ratio	Total bank debt outstanding at the end of the year (`loan` and `cred`) as a fraction of total assets (`toas`).
Interest burden	Total expenses on interest payments (`interest`) and other financial expenses (`fiex`) as a fraction of the unweighted average debt holdings during the year ($= (\texttt{liab}_t + \texttt{liab}_{t-1})/2$), where `liab` is the sum of current `culi` and non-current liabilities (`ncli`).

(*continued on next page*)

Table A2: *continued*

Firm-level controls (continued)	
Firm size*	Logarithm of total assets (`toas`); winsorized at 1 percent level.
Tangibility*	Total tangible fixed assets (`tfas`) as a share of total assets (`toas`).
Cash-flow ratio*	Total cash flow (`cf`) as a share of total assets (`toas`); winsorized at 1 percent level.
Profitability (RoA) *	Return on assets, i.e., total end-of-year profits (`pl`) over total assets (`toas`); winsorized at 1 percent level.
Listed	Dummy = 1 if a firm is listed on the stock market (`Listed`="Listed") and zero otherwise.
Firm age	Time (full years) between incorporation date (`Date_of_incorporation`) and the balance sheet reporting date (`Closing_date`).
# Employees	Total number of employees at the end of the period (`empl`).
Employment growth	Year-over-year growth rate of the total number of employees at the end of the period (`empl`), calculated as ($\texttt{empl}_t$-$\texttt{empl}_{t-1}$)/$\texttt{empl}_{t-1}$.
Investment growth	Year-over-year growth rate of the total investments (ttl_inv) during the period (`exp_mat`, `exp_staf`), and `oope`) calculated as (ttl_inv$_t$-ttl_inv$_{t-1}$)/ttl_inv$_{t-1}$.
PatExp	Measures the total Euro value of patent-related fee payments of a firm in any given year. Fees accrue for application and maintenance of patents. Values are obtained from Gill and Heller (2022).
PatExp-to-assets	Ratio of patenting expenses to total assets (`toas`).
PatExp-to-expenses	Ratio of patenting expenses to total expenses, which comprise the total costs of goods sold (`cost`), expenses on employee salaries (`exp_staf`), other operating expenditures (`oope`), and capital expenditures (`exp_mat`) within a given year.
PatExp-to-opex	Ratio of patenting expenses to operating expenses (`cost`; `oope`).
PatExp-to-capex	Ratio of patenting expenses to total capital expenditures (`exp_mat`).
PatExp-to-total-debt	Ratio of patenting expenses to total liabilities (`culi`; `ncli`).
PatExp-to-bank-debt	Ratio of patenting expenses to total bank debt (`loan`; `cred`).
Macro-level controls:	
Economic conditions	Per-capita GDP measured on the country-year level.
Productivity	Labor productivity (output per hours worked).
Financial development	Banking sector Herfindahl-index.
Business cycle	ECB financial distress indicator.

(*continued on next page*)

Table A2: *continued*

Patenting variables:	
Patent filings	Total count of priority patent filings at any jurisdiction.
Forward citations	All citations received within the first seven years after filing of patents filed by a firm; citations are determined ex post.
Claims	The normalized number of claims included in all applications of a firm as a share of backward citations.
Family size	The (maximum) number of jurisdictions in which patents will be protected at one point of their life.
Renewals	The average renewals all filed patents in a given year eventually receive.
Incremental	Incremental patents do *not* fulfill the two criteria of being a patent of high quality patent nor a broad scope patent.
Explorative	Explorative patents fulfill the two criteria of being a patent of high quality patent and having a broad scope.
High-impact	Impact is high if a patent fulfills three of the following criteria: it is cited at least once in the first seven years after filing, it has above average normalized forward citations in its year-industry cohort and above average claims ratio, at least 80% of references are of A-type (indicating novelty).
Technological diverse	Technological diversity applies if a patent has both a patent scope and a IPC-class concentration (patent *generality*) above the year-industry cohort average. Patent scope refers to the number of distinct 4-digit IPC classes, while generality measures the IPC class concentration of a patent.

Notes: The table defines all variables used in the empirical analyses. The list includes the original ORBIS labels of observable firm characteristics whenever applicable. Macro-controls are obtained from the OECD's statistical database (OECD.Stats) and the European Central Bank data warehouse. Firm-level financial variables marked with * are the "firm level" control variables used in all regressions unless specified otherwise. Patent variables are defined at the firm-year level and determined ex-post. Appendix B contains further details on the patenting variables.

Table A3: Sample distribution across sectors (NACE Rev. 2)

Category	Firms	(in %)	Patents	(in %)
A - Agriculture, forestry, and fishing	102	(0.46)	1,007	(0.14)
B - Mining and quarrying	97	(0.44)	10,201	(1.45)
C - Manufacturing	11,746	(53.00)	447,027	(63.55)
10 - Food products	2,240	(2.54)	6,684	(1.50)
11 - Beverages	271	(0.31)	543	(0.13)
12 - Tobacco products	67	(0.08)	488	(0.07)
13 - Textiles	1,658	(1.88)	2,229	(0.50)
14 - Wearing apparel	545	(0.62)	464	(0.12)
15 - Leather and related products	319	(0.44)	373	(0.11)
16 - Wood products, excluding furniture	1,441	(1.63)	1,502	(0.34)
17 - Paper and paper products	1,723	(1.95)	7,515	(1.68)
18 - Printing and reprod. of rec. media	959	(1.09)	981	(0.22)
19 - Coke and petroleum	172	(0.19)	1,194	(0.26)
20 - Chemicals and chemical prod.	5,196	(5.89)	56,010	(12.53)
21 - Pharmaceuticals	2,570	(2.91)	35,729	(7.99)
22 - Rubber and plastics	7,003	(7.93)	22,676	(5.07)
23 - Other non-metallic mineral prod.	2,967	(3.36)	9,631	(2.15)
24 - Basic metals	1,643	(1.86)	7,712	(1.73)
25 - Fabricated metals	11,842	(13.41)	24,873	(5.56)
26 - Computer, electronics, optical prod.	9,940	(11.26)	40,755	(9.12)
27 - Electrical equipment	6,342	(7.18)	39,225	(8.77)
28 - Machinery (n.e.c.)	17,383	(19.69)	79,191	(17.72)
29 - Motor vehicles	2,822	(3.20)	61,895	(13.85)
30 - Other transport equipment	1,738	(1.97)	17,488	(3.91)
31 - Furniture	1,439	(1.63)	1,877	(0.42)
32 - Other machinery	6,345	(7.19)	20,833	(4.66)
33 - Repair and install. of machinery	1,578	(1.79)	7,111	(1.59)
D - Electricity and gas	108	(0.49)	1,728	(0.25)
E - Water supply	133	(0.60)	802	(0.11)
F - Construction	823	(3.71)	7,515	(1.07)
G - Wholesale and retail trade	3,066	(13.84)	42,498	(6.04)
H - Transportation and storage	166	(0.75)	7,594	(1.08)
I - Accommodation	47	(0.21)	292	(0.04)
J - Information and communication	1,254	(5.66)	21,675	(3.08)
L - Real estate	174	(0.79)	1,641	(0.23)
M - Professional, scientific, tech. activities	3,529	(15.92)	126,763	(18.02)
N - Administration	678	(3.06)	31,316	(4.45)
Q - Human health	149	(0.67)	2,299	(0.33)
R - Arts, entertainment	89	(0.40)	1,020	(0.15)
Total	22,161	(100.00)	703,378	(100.00)

Notes: The table displays the distribution of observations in the main sample across sectors according to NACE Rev. 2 main categories. The table includes the corresponding values for the number of patents filed by sample firms in each sector, including the shares as fractions of the total indicated in parentheses next to respective values. For the manufacturing sector, the shares of the sub-sectors (categories 10-33) are represented separately.

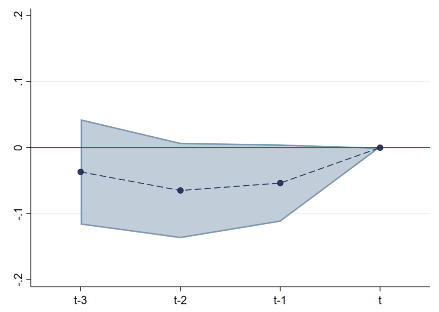
Table A4: Pre-treatment DID regression coefficients: Testing for parallel trend

Panel A: Descriptive statistics on constrained versus unconstrained firms

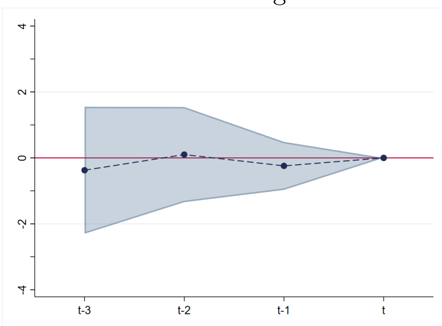
	Constrained = 1				*Constrained* = 0			
Variable	**Mean**	**Q25**	**Q50**	**Q75**	**Mean**	**Q25**	**Q50**	**Q75**
Firm age	12.991	4	7	12	33.54	16	25	42
Firm size	8.363	5.595	7.650	11.300	9.154	7.983	9.092	10.300
Tangibility	0.210	0.032	0.107	0.289	0.202	0.061	0.151	0.296
Cash-flow ratio	0.027	-0.007	0.077	0.138	0.090	0.042	0.090	0.149
Profitability (RoA)	0.067	-0.005	0.049	0.132	0.056	0.007	0.047	0.104
Bank debt (log.)	6.249	3.526	5.866	9.376	7.160	6.019	7.422	8.720
Bank loan ratio	0.223	0.066	0.158	0.302	0.247	0.098	0.206	0.354

Panel B: Anticipatory effects on main outcome variables

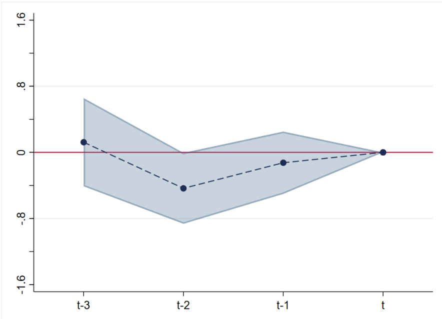
Bank loans:



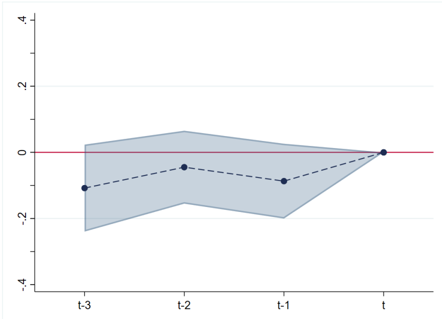
Patent filings:



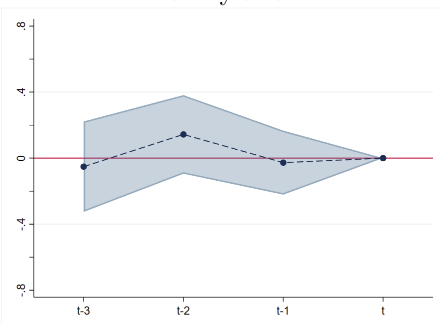
Forward citations:



Claims:



Family size:



Renewals:

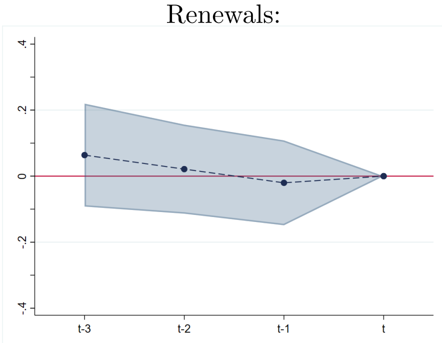


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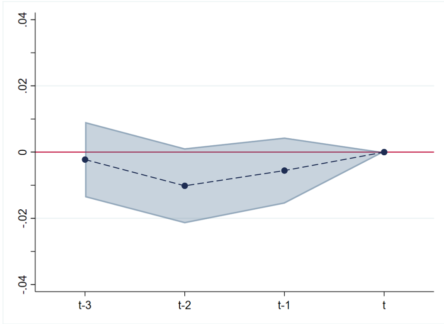
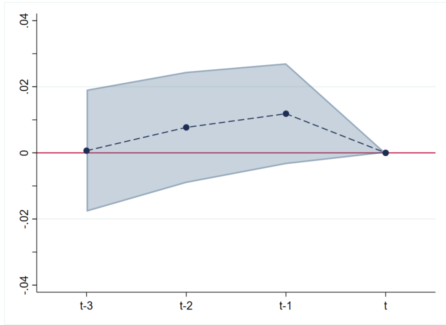
Table A4 (*continued*)

Panel B: *continued*

Incremental:



Explorative:



Panel C: Pre-treatment trend regarding different patenting dimensions

Patenting dimensions:			Technological quality	
Dependent variables:	Bank debt (log.)	Patent filings	Fwd citations	Claims
	(Ia)	(IIa)	(IIIa)	(IVa)
Constrained × Trend	0.019	0.214	0.077	0.025
	(0.014)	(0.316)	(0.069)	(0.018)
Trend	0.001	-0.200	-0.042	-0.044
	(0.035)	(0.169)	(0.211)	(0.030)
Patenting dimensions:	Market value		Patent types	
Dependent variables:	Family size	Renewals	Incremental	Explorative
	(Ib)	(IIb)	(IIIb)	(IVb)
Constrained × Trend	-0.068	-0.009	0.004	-0.001
	(0.043)	(0.021)	(0.003)	(0.002)
Trend	-0.144*	-0.270***	0.005	0.006*
	(0.084)	(0.044)	(0.005)	(0.003)
Additional controls:				
Firm-level	Yes	Yes	Yes	Yes
Macro-level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Observations (top panel)	30,040	55,177	19,474	19,474
Observations (bottom panel)	19,474	19,474	19,474	19,474

Notes: Panel A displays summary statistics on the key variables for firms considered as ex-ante financially constrained ($Constrained = 1$) and unconstrained ($Constrained = 0$) in the main specifications; measured by the median split of the pre-FSAP S&A scores of sample firms. Panel B and C display tests on parallel trends between treated and control group firms during the pre-FSAP integration phase. Panel B plots coefficients of the interaction terms of year- and treatment dummy variables. Year dummies resemble the country-specific years before the treatment is initiated, i.e., $FI < 0.2$. All other variables and the model specifications are defined as in the baseline specification, e.g., Tables 3 and 4. The shaded area represents the 95 percent confidence intervals of the estimates. Panel C uses the same subsample of pre-treatment years and presents regression estimates similar to the baseline specification, only here regressions 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 *Constrained*, indicating whether a firm is ex-ante financially constrained ("treated") or not (see Section 4.1). Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table A5: Robustness tests: alternative specifications of the baseline estimations

Panel A: Main specifications using the *de facto* financial integration measure

Dependent variable:	Bank debt (log.)		Interest burden	
	(I)	(II)	(III)	(IV)
FI × *Constrained*	0.537***	0.307***	-0.011**	-0.010**
	(0.063)	(0.059)	(0.005)	(0.004)
Constrained	-0.409***		0.021***	
	(0.049)		(0.004)	
FI	0.524***		0.030***	
	(0.070)		(0.004)	
Additional controls:				
Firm level	Yes	No	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
R^2	0.69	0.90	0.05	0.60
Observations	115,906	115,906	54,205	53,877

Panel B: Alternative definition of debt financing as dependent variable

Dependent variable:	Debt-to-asset ratio			
	(I)	(II)	(III)	(IV)
FI × *Constrained*	0.025***	0.011***	0.016***	0.008***
	(0.004)	(0.004)	(0.005)	(0.003)
Constrained	-0.033***			
	(0.004)			
FI	0.048***			
	(0.006)			
FI definition:	de jure	de jure	de facto	2004-dummy
Additional controls:				
Firm level	Yes	Yes	Yes	Yes
Macro level	Yes	No	No	No
Industry-FE	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes
Country-Year-FE	No	Yes	Yes	Yes
R^2	0.69	0.90	0.89	0.90
Observations	115,906	115,906	115,906	115,906

(*continued on next page*)

Table A5: *continued*

Panel C: Robustness tests: Using variants of the *de jure* financial integration measure

Dependent variable:	Bank debt (log.)					
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × *Constrained*	0.191***	0.091***	0.215***	0.104***	0.090***	0.051***
	(0.024)	(0.020)	(0.028)	(0.023)	(0.023)	(0.019)
Constrained	-0.146***		-0.167***		-0.064***	
	(0.027)		(0.028)		(0.023)	
FI	0.246***		0.561***		0.283***	
	(0.031)		(0.050)		(0.029)	
FI definition:	2004-dummy		2004-Directives		CapReq Directives	
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
R^2	0.69	0.90	0.69	0.90	0.69	0.90
Observations	115,906	115,906	115,906	115,906	115,906	115,906

Notes: The table presents robustness tests on the main regressions that analyze the effect of the FSAP on debt financing activities. Columns I and II are equivalent to Columns I and IV in Panel A of Table 3 but measure financial integration using the *de facto* measure of financial integration instead of the de jure measure. Columns III and IV repeat this analysis but use firms' interest burden as the dependent variable, equivalent to Panel B of Table 3. Panel B uses alternative definitions of debt financing as the dependent variable, namely the bank debt-to-assets ratio as defined in Table A2 (Appendix A). Otherwise, Columns I-III are equivalent to Columns I-III in Panel A of Table 3. Column IV repeats Column III but uses a dummy variable equal to one for all years after 2004 and zero otherwise to measure the FSAP. Panel C displays robustness tests using different variants of the *de jure* measure of integration and follows the main specifications from Columns I and II in Panel A of Table 3. In Columns I and II, integration is operationalized using a dummy variable equal to one for all years following 2004, capturing the year in which several FSAP amendments were implemented and the de facto measure surged. Columns III and IV use the same de jure measure calculation as defined in Equation (1) but only consider the three Directives that were implemented in 2004. Columns V and VI again use the same calculation as in Equation (1) but only consider the Capital Requirements Directive as one of the major amendments of the FSAP. 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 levels, respectively.

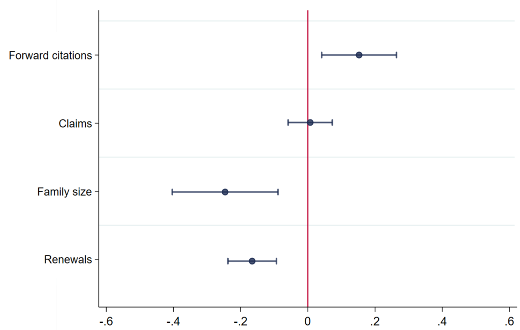
Table A6: Financial integration and patenting: robustness tests

Panel A: Different variants of the main specification

Dependent variable:	Patent filings			
	(I)	(II)	(III)	(IV)
FI × *Constrained*	0.151*** (0.033)	0.273*** (0.050)	0.186*** (0.046)	0.066** (0.032)
Adjusted variable:	FI	*Constrained*	Patent filings	
Model specification:	2004-dummy	Q75	Normalized	log.
Additional controls:				
Firm level	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes
Observations	115,906	115,906	115,906	115,906

Panel B: Coefficient plots: The effect of the FSAP on patent quality dimensions

Technological quality and market value:



Patent types:

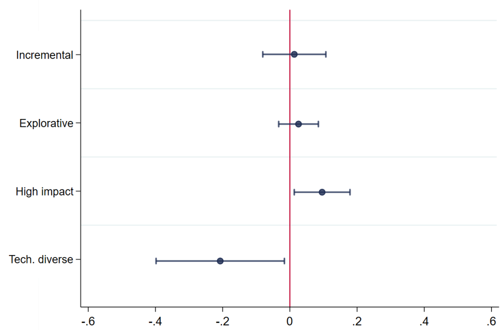


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Table A6: *Continued*

Panel C: Main specification using maximum values of patent quality measures

Patenting dimensions:	Technological quality				Market value			
Dependent variables:	Forward citations		Claims		Family size		Renewals	
	Max.	*Norm.*	*Max.*	*Norm.*	*Max.*	*Norm.*	*Max.*	*Norm.*
	(Ia)	(Ib)	(IIa)	(IIb)	(IIIa)	(IIIb)	(IVa)	(IVb)
FI × *Constrained*	0.425	0.018^{***}	0.123	0.015^{**}	-0.318^{**}	-0.010^{*}	-0.722^{***}	-0.027^{***}
	(0.510)	(0.005)	(0.173)	(0.006)	(0.132)	(0.006)	(0.123)	(0.006)
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.58	0.43	0.54	0.42	0.79	0.73	0.56	0.43
Observations	46,937	46,937	46,937	46,937	46,937	46,937	46,937	46,826

Notes: This table presents robustness tests on the main regressions explaining firms' patenting activities. Panel A displays estimates on different variants of the baseline regression using patent filings as the dependent variable, similar to Panel A of Table 4. In Column I, the integration variable is modified compared to the baseline analyses and is coded as a dummy equal to one for all years after 2004. Column II uses another alternative definition of the de jure integration measure, i.e., where financially constrained firms are only those on the top quartile of the S&A distribution. Column III uses the normalized patent filing values as an alternative specification of the dependent variable. Normalization is achieved by dividing the number of patent filings by the maximum patent filings in the industry-year cohort, i.e., 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. Column IV uses the logarithm of patent filings as the dependent variable, and the estimation method is OLS. Panel B plots coefficients of the DID estimates deployed in fixed effects panel regressions equivalent to Column III in Table 4 (Panel B). The outcome variables are the different patenting dimensions regarding patent quality and value (left figure) and patent type (right figure) as defined in Table 2. Whiskers span the 95 percent confidence intervals. Panel C presents estimates from panel regressions explaining the effect of the FSAP on the full set of patent quality- and market value-related measures as introduced in Section 3.2. The table displays the DID coefficients equivalent to Column III in Table 4, using respective measures as dependent variables. All columns denoted with a measure the respective dependent variables by the maximum value in each year. All columns denoted with b measure the respective dependent variables normalized by industry-year cohort values – just like in Panel A. 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 levels, respectively.

Table A7: Controlling for regional effects and spatial dynamics

Patenting dimensions:	Bank debt (log.)				Patent filings			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × *Constrained*	0.127***	0.138***	0.150***	0.085***	0.219***	0.218***	0.158***	0.191***
	(0.034)	(0.034)	(0.034)	(0.031)	(0.054)	(0.053)	(0.060)	(0.065)
Constrained	-0.122***	-0.129***	-0.135***		0.319***	0.320**	0.360***	
	(0.030)	(0.030)	(0.030)		(0.056)	(0.056)	(0.060)	
FI	-0.222***	-0.460***			0.031	-0.045		
	(0.049)	(0.087)			(0.068)	(0.140)		
Additional controls:								
Firm level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro level	Yes	No	No	No	Yes	No	No	No
Industry FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
NUTS3 FE	Yes	Yes	No	No	Yes	Yes	No	No
Year FE	No	Yes	No	No	No	Yes	No	No
Firm-FE	No	No	No	Yes	No	No	No	Yes
NUTS3-Year FE	No	No	Yes	Yes	No	No	Yes	Yes
R^2	0.75	0.75	0.76	0.91	0.39	0.39	0.41	0.76
Observations	81,043	81,043	81,043	81,043	80,233	80,233	80,233	80,233

Notes: These tables present estimates on regressions similar to the baseline specifications explaining debt financing (Columns I-IV) and patent filings (Columns V-VIII), respectively, but additionally control for regional effects. Regions are measured by the Nomenclature of Territorial Units for Statistics (NUTS), using the most granular regional level, NUTS-3. Column I is equivalent to Column I of Table 3 Panel A but adds NUTS3 fixed effects. In Column II, regressions additionally include year fixed effects. Column III adds NUTS3-year effects, and Column IV is similar to Column II in Table 3, but includes NUTS3-year fixed effects instead of country-year fixed effects. Columns V-VIII follow the same pattern but estimate the effect of the FSAP on patenting activities, as outlined in Panel A of Table 4. 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 levels, respectively.

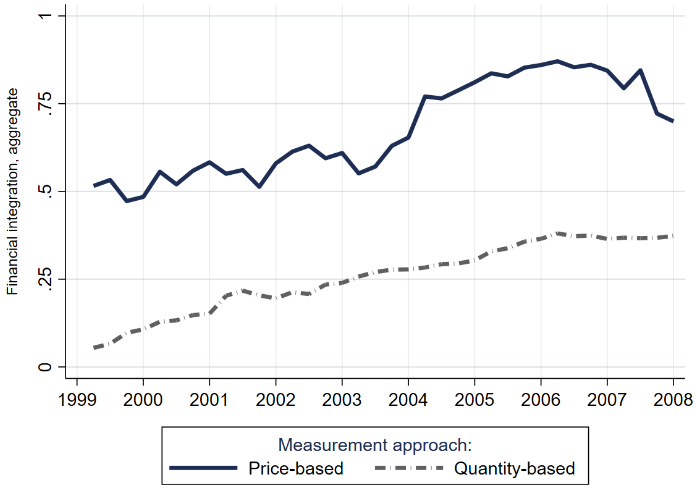
Table A8: Patent quality estimations using the placebo event

	Technological quality			
Dependent Variable:	Forward Citations		Claims	
Treatment measure:	Binary	Continuous	Binary	Continuous
	(I)	(II)	(III)	(IV)
$FI^{\text{placebo}} \times Constrained$	0.082	0.210	0.019	0.111
	(0.166)	(0.245)	(0.054)	(0.080)
	Market value			
Dependent Variable:	Family size		Renewals	
Treatment measure:	Binary	Continuous	Binary	Continuous
	(I)	(II)	(III)	(IV)
$FI^{\text{placebo}} \times Constrained$	-0.029	-0.041	-0.097	-0.102
	(0.149)	(0.208)	(0.063)	(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 a set of robustness tests on the placebo setting. The placebo estimations are identical to Columns II and IV in Table 7, except that they use the patent quality and market value variables defined in Table 2 as dependent variables. All remaining variables are defined as in the baseline specification but use the alternative time window between 1996-2004. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Figure A1: Financial market integration measures: additional perspectives

Panel A: Price- and quantity-based *aggregate* de facto measures



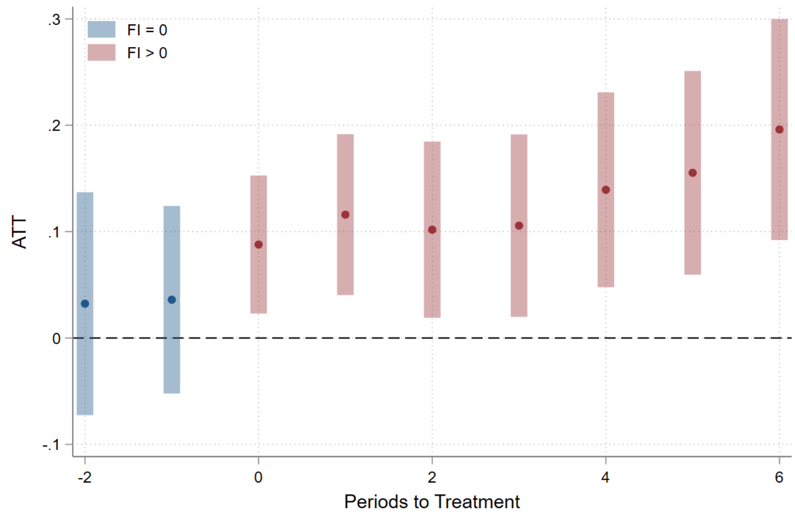
Panel B: Comparing de jure and de facto measures

Measure	Country	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
De jure	BE	0	0	0	0	0.13	0.34	0.62	0.70	0.98	1
	DE	0	0	0	0.10	0.18	0.34	0.62	0.70	0.98	1
	FI	0	0	0	0	0.18	0.40	0.54	0.70	0.98	1
	FR	0	0	0	0	0.14	0.42	0.62	0.70	0.98	1
	GB	0	0	0	0.09	0.13	0.36	0.62	0.70	0.98	1
	IT	0	0	0	0.09	0.13	0.34	0.62	0.70	0.98	1
	NL	0	0	0	0.10	0.18	0.31	0.54	0.57	0.98	1
	SE	0	0	0	0.09	0.13	0.13	0.43	0.70	0.98	1
	Avg.	0	0	0	0.06	0.15	0.33	0.58	0.69	0.98	1
De facto	All	0.19	0.28	0.48	0.45	0.53	0.83	0.84	0.82	0.84	0.82

Notes: Panel A plots *de facto* measures of financial integration for the years from 1999 to 2008. The data is obtained from Hoffmann *et al.* (2020). The dashed line refers to the ECB's quantity-based composite indicator measuring monetary financial institutions' (MFI) loans to non-financial corporations. The quantity-based indicators use data on the international portfolio composition of MFIs. The indicators are computed as intra-euro area cross-border holdings expressed as a share of euro area total holdings. The solid line resembles the ECB's price-based composite indicator measuring standard deviations of MFI interest rates on new loans to non-financial corporations and households. For both measures, the aggregate figures are displayed on a quarterly level. See Hoffmann *et al.* (2020) for a detailed description of the different measures. Panel B displays the de jure and de facto values of financial integration on a year-by-year basis. The de jure measure varies across countries, whereas the de facto measure is the same for all countries. Both cases do not refer to an aggregate measure (as in Panel A) but display the banking market segment integration, i.e., the numbers are the numerical expressions of Figure 1.

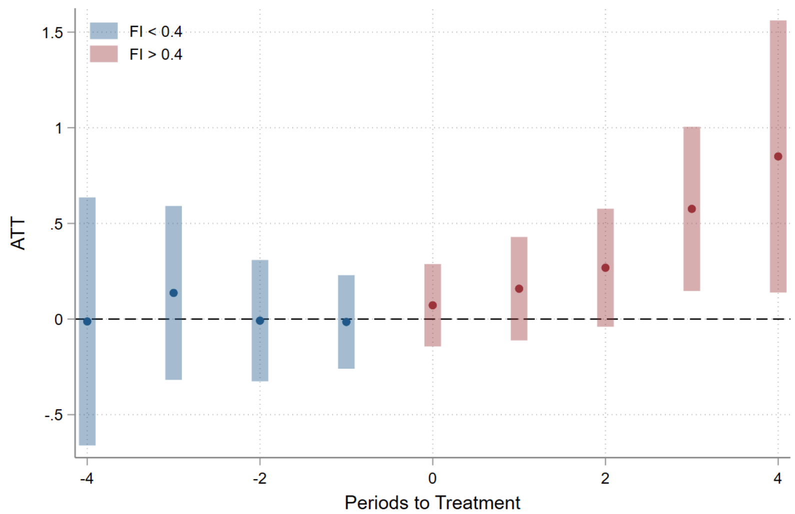
Figure A2: Dynamic treatment effects: Callaway and Sant'Anna (2021) DID plot

Panel A: Debt financing:



	Coef.	SE	z	P> $\|z\|$	[95% conf.	interval]
Pre_avg	0.034	0.033	1.03	0.305	-0.031	0.099
Post_avg	0.129	0.036	3.62	0.000	0.059	0.199

Panel B: Patenting activities:



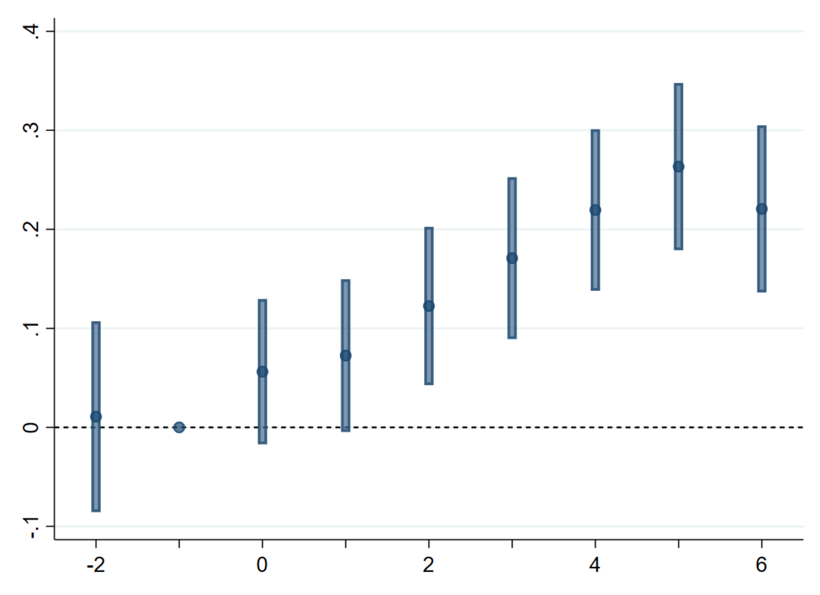
	Coef.	SE	z	P> $\|z\|$	[95% conf.	interval]
Pre_avg	0.025	0.102	0.25	0.804	-0.174	0.224
Post_avg	0.385	0.155	2.49	0.013	0.082	0.688

(*continued on next page*)

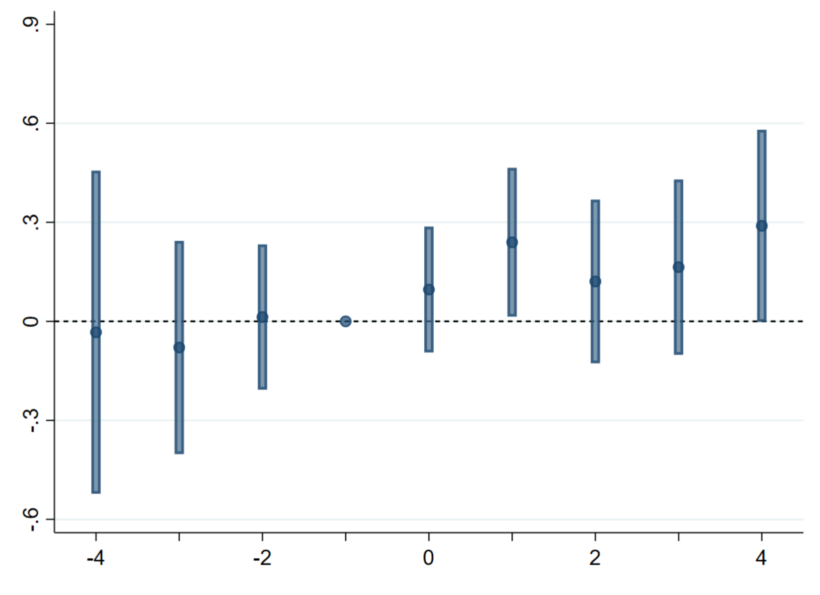
Figure A2 *(continued)*

Panel C: Replicating the CS approach using Cengiz *et al.* (2019)

Debt financing:

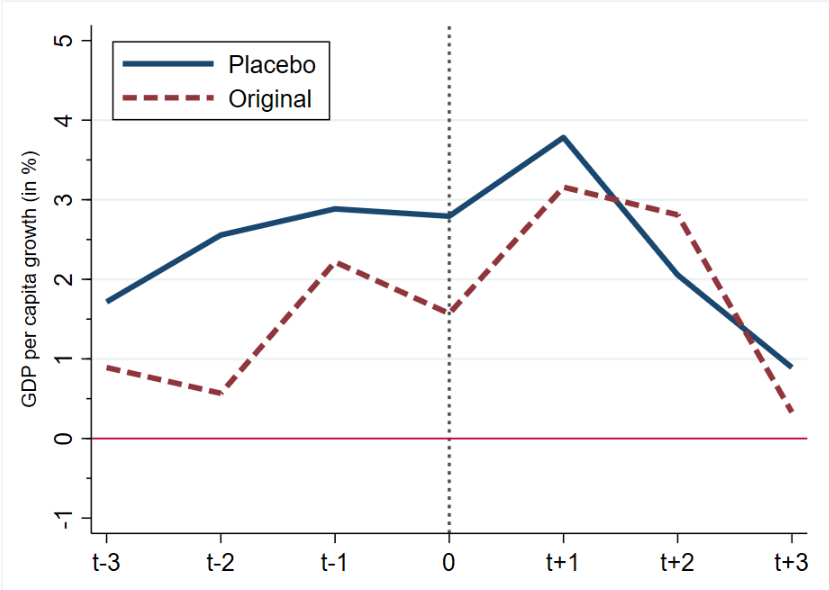


Patenting activities:



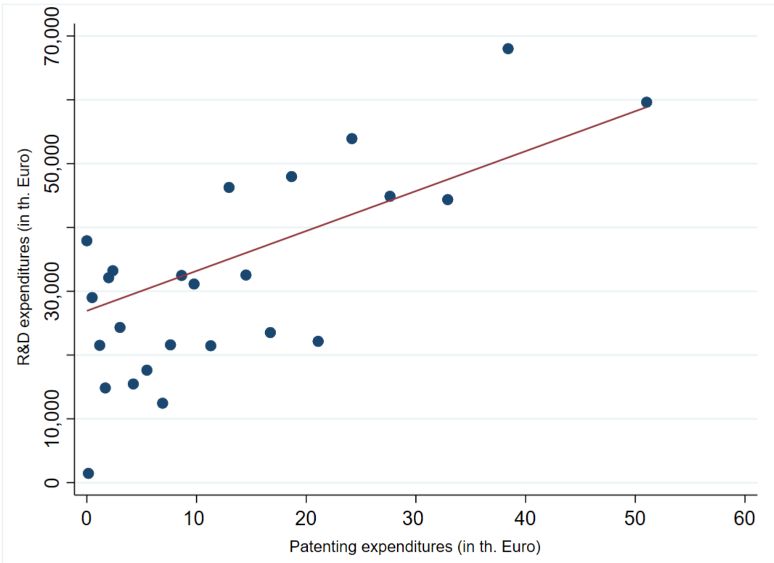
Notes: This graphs illustrate dynamic treatment effects using the Callaway and Sant'Anna (2021) metric for estimating the effect of the FSAP on firm-level debt financing and patenting activities. Here, the first effective year of the FSAP is defined as the year in which the FI-measure as defined in Equation (1) exceeds 0. Estimations are implemented using the *csdid* command in Stata and display the aggregated average treatment effect on the treated (in the first row denoted as "*CAverage*") and the dynamic treatment effects by year. The whiskers span the 95 percent confidence intervals of the estimates. Panel C repeats the first two estimations but uses as an alternative specification approach, suggested in Cengiz *et al.* (2019) and implemeted in Stata via the *stackedev* command. This approach requires a reference period, which is set in line with the specifications in the first two panels as the last country-specific year in which the FI-measure is 0 (debt financing) or 0.4 (patenting), respectively.

Figure A3: GDP growth rates in the time windows around the placebo and original events



Notes: This graph illustrates the macroeconomic conditions during the original event window (2001-2007) and the placebo event window (1996-2002). The lines plot the GDP per capita growth rates of the European Union during respective years. The years relative to the treatment (t) are denoted on the horizontal axis. For the actual event, this is when the FI measure defined in Equation (1) exceeds 0.5, that is, in 2004. For the placebo event, t is the year 1999, marking the year the Euro was introduced as the official currency among Eurozone countries.

Figure A4: The relationship between R&D- and patenting expenditures



Notes: This binned scatterplot graphically displays the relationship between sample firms' expenditures on research and development (y-axis) and patenting expenditures (x-axis). R&D data is from the original ORBIS data, and patent expenditures data is from Gill and Heller (2022). The values refer to the total annual expenditures of firms in a given year, both denoted in thousand Euros. The number of bins is set to 25.

Appendix B : Defining relevant patenting dimensions

Measuring patent quality: A well-known dimension of patent quality is forward citations (e.g., Trajtenberg 1990). Citations refer to the number of references a particular patent document receives; both granted and non-granted patents (i.e., published applications) can be cited. The number of forward citations mirrors the technological importance of a patent for subsequent technologies and indicates the economic value of inventions (de Rassenfosse and Jaffe 2018). Therefore, a higher citation count indicates higher patent quality in technological terms. Measuring patent quality through citations is advantageous, as it is a straightforward approach and can be applied to patents from any jurisdiction worldwide. Still, using citation data also entails disadvantages; for example, they can only be determined ex-post and may have unfavorable properties, i.e., distributions are strongly skewed, with most patents receiving zero or very few citations (de Rassenfosse and Jaffe 2017). Citations should be considered only within a certain time lag after the initial application to warrant better comparability of patents from different year cohorts. In the main analysis, I follow related literature and consider citations made within the first seven years after publication (e.g., Harhoff *et al.* 2003).

Patent claims are a another dimension of patents' technological quality. According to the European Patent Convention (EPC, 1973), patent claims "*define the matter for which protection is sought*" (Art. 84). A patent can have multiple claims, and only the technology covered in claims can be legally protected and enforced. Thus, claims approximate the size of the monopoly right attributed to the patented invention. Literature shows that claims reflect patents' technological breadth as they determine the boundaries of the exclusive rights of a patent owner (e.g., Marco *et al.* 2019). Unlike citations, claims can be determined at the time of the first publication of a patent (but they are subject to change until grant). However, claims have less variation, which may impede identifying patents of exceptionally high impact. Just like citations, the number of claims included is a readily observable measure of the quality of a patent. In the empirical analyses, I normalize claims using backward citations, i.e., references made by a focal patent to prior art.

Value-related measures: There are specific measures related to the value of a patent. Yet, differentiating between patents' technological quality and patent value is challenging. Ceteris paribus, a patent of high technological quality should deliver relatively high economic value for its owner. However, the reverse is not necessarily true: some factors affect market value despite being unrelated to the quality of a patent. For example, the size and regulatory framework of a patent owner's market affect the potential to extract value from a given invention, irrespective of its quality (Aghion *et al.* 2013). Consistently, the econometric analyses follow related work and differentiate among factors that are relevant for both patent quality and value as well as those that are only considered value relevant (e.g., Hall *et al.* 2005; de Rassenfosse and Jaffe 2018).

The first market value measure considers the number of jurisdictions in which a patent is active, 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 state once their patent application is approved. Despite international agreements, patent rights, in general, remain national rights that have to be extended on a country-by-country basis. 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 positively related to patent value (Lanjouw *et al.* 1998; Harhoff *et al.* 2003; Hall *et al.* 2005). I estimate a patent's family size by counting the number of patent offices at which the patent was filed throughout its lifetime.

Second, to perpetuate the protection of a patent, firms have to pay administrative fees up to a maximum of 20 years after initial approval (exceptions included). Renewal fees may vary substantially across jurisdictions worldwide in magnitude, type, and frequency (de la Potterie 2010). In Europe, renewal fees are due annually, beginning with the third year of protection, and increase over a patent's lifespan as stipulated in Article 86 of the EPC (1973). See Gill and Heller (2022) for a detailed description of the European patenting fee schedule. Once the fee is not paid within the first six months of the due date, the patent is automatically withdrawn, and protection terminates. As such, renewal fee payments are a direct indicator of the validity of a patent. More importantly, the number of renewals indicates patent value: Because of the repeated decision to incur annual renewal costs, in expectation, valuable patents will be renewed more often than less valuable patents (Schankerman and Pakes 1986; Harhoff *et al.* 2009). To operationalize this measure, I count the ex-post-determined number of patent renewals.

Invention types: Regarding the overall direction of an invention, literature commonly differentiates between 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; Beck *et al.* 2016). For the innovative process as a whole, a mix of minor steps and radical jumps, i.e., incremental and explorative inventions. In the empirical analyses, I, therefore, distinguish explorative and incremental and determine these dimensions based on the four patent dimensions defined above, i.e., patents' technological quality and market value.

(a) Explorative patents:

Key technologies are decisive 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 simultaneously. They are associated with fostering 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: It should exhibit general applicability relevant to the functioning of a broad set of products or processes, have the potential for sustained optimization, and feature a high degree of complementarity, particularly in downstream sectors (Bresnahan and Trajtenberg 1995; Trajtenberg *et al.* 1997). The combination of these features suggests a long-lasting impact on productivity and output.

For identifying the degree of generality of a patent, the measurement strategy in this paper uses information on the patent scope and impact. The scope of a patent – or its degree of technological diversity – can be defined by deriving distinct technology classes (i.e., 4-digit IPC subclasses) that cite a focal patent. I follow prior literature and consider different weights in the distribution across IPC classes by measuring the patent scope using a concentration index, i.e., Herfindahl index of technology classes (see Trajtenberg *et al.* 1997). The measure ranges between one and zero, indicating a high or low concentration of IPC classes, whereby a score of one resembles a patent that relates to one distinct IPC class. Moreover, relative to other inventions, an high technological diversity should also be reflected in the number of patent claims. A large number of claims resembles respective patents' relatively broad applicability, high complementarity, and, hence, higher scope. Based on these considerations, the empirical analyses consider patents to be technologically diverse if they have a low IPC concentration and relatively many claims.

To identify high-impact patents, the analyses in this paper consider four criteria. First, a high patent claims ratio, as defined above, indicates a high degree of novelty and impact. Second, a patent must have received at least one citation (excluding self-citations) to have any impact on subsequent inventions. Third, to further specify the impact of a patent, the number of citations received has to be sufficiently large compared with the annual average of all citations received by patents in the same industry. Fourth, the type of references included indicates a reference's relevance. Specifically, the most common classifications are X-, Y-, and A-type references. Only references of category A reflect that a reference is not prejudicial to the novelty or inventive step of the claimed invention.[22] Hence, high-impact patents should include a high share of A-type references. As proposed in the empirical analysis and based on the criteria outlined here, high-impact patents should fulfill at least three out of the following four aspects: They have i) an above-average claims ratio, ii) at least one citation, iii) an above-average number of citation relative the industry-year cohort, and iv) at least 80% of citations have to be A-type references.

I consider these characteristics of patent scope and impact to flag explorative patents. An

[22]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 combined with at least one other document is such that a claimed invention cannot be considered an inventive step.

explorative patent has both characteristics; it qualifies as a high-impact patent and fulfills both scope criteria. The analyses also use the two dimensions separately (referred to as “high-impact” and “technologically diverse” patents), allowing a more differential perspective.

(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. Innovation is often considered a cumulative process and, thus, strongly depends on small and steady improvements. As such, incremental inventions may also enhance the efficiency of existing technologies by improving inventions step-by-step (Beck *et al.* 2016; Kobarg *et al.* 2019).

To quantify whether a patent can be considered incremental, I consider the same proxies for the patent scope and impact that are also relevant to determine explorative patents. An incremental patent has more narrow boundaries and, thus, a lower patent scope and fewer claims relative to other patents. By definition, incremental inventions should receive less attention than high-impact patents. Thus, I propose that incremental patents must fulfill the two criteria: they are neither technologically diverse nor high-impact patents. This logic implies that incremental and explorative patents are mutually exclusive . However, a patent can be both not incremental and not explorative, which underlines the specific character of these two patent types.