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

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This paper provides new evidence on the effects of financial market integration on firm-level external debt financing and subsequent inventive activities. I exploit the implementation of the Financial Services Action Plan (FSAP) as an exogenous event that significantly raised financial integration in Europe during the 2000s. Estimates show large positive effects of the FSAP on firms' use of debt and subsequent patent filings but moderate adverse effects along different qualitative dimensions of patenting, particularly for ex-ante patenting-intensive firms. In contrast, the FSAP significantly raised patent quantity and quality for firms with low pre-treatment patenting intensities. These findings highlight the key role of a conducive financing environment for inventive activities but also reveal unintended effects of policy-induced improvements in access to financing in the spirit of a quantity-quality tradeoff in patenting activities. Overall, this paper discloses crucial insights into the role of firms' financing environment for inventive activities, improving our understanding of effective policy design at the governmental and firm levels.

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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). Enhanced financial market integration improves firms' access to debt financing (Haselmann *et al.* 2009; Liberti and Mian 2010), which is an important funding source for research-intensive firms (Kerr and Nanda 2015; Mann 2018). 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 inducing innovative efficiency of individuals and firms (Ederer and Manso 2013; 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 seven bank-related FSAP amendments as a traceable, exogenous source of variation in the legal environment, improving firms' borrowing conditions across EU member states during the early 2000s. The analyses answer whether increased financial integration improved access to debt financing and how this translated to the inventive activities of affected firms. Importantly, I measure the quantity and quality of patent output as inventive activities. Taking these two complementary dimensions into account is crucial because they are both relevant for the potential to create value in the long run and, thus, the economic success of firms (Harhoff and Wagner 2009; de Rassenfosse 2013). Moreover, this differential perspective acknowledges that increased patenting activities do not necessarily imply more innovation, an observation referred to as the patent paradox (Hall and Ziedonis 2001; Klein 2020).

To identify the effect of the FSAP on firm-level outcomes, the analyses exploit additional cross-sectional variation. Variation arises from firms' ex-ante degree of financing constraints, distinguishing relatively more or less constrained firms (i.e., 'treated' and 'control' firms). Using a large-scale sample that includes primarily small and medium-sized firms from eight European countries and data on more than 700,000 patent applications, I first show that the FSAP amendments enhanced firms' debt capacity. As such, the average use of debt increases by about 12% for treated firms, and the average interest charge decreases by about 6% comparing pre- and post-integration levels relative to firms in the control group.

[1] Efficiency effects of financing constraints have to be limited since ever fewer resources cannot lead to ever more or better inventions. However, anecdotal and empirical evidence finds a financing-induced quantity-quality tradeoff in patenting activities. In 2018, the British Patent Office announced to raise patenting fees substantially in order to "*encourage good filing practices by applicants*" (UKIPO 2018). Echoing this, empirical evidence shows that higher application fees reduce the number of patent filings but predominantly crowd out low-quality applications and, thus, enhance average patent quality (Eaton *et al.* 2004; de Rassenfosse and Jaffe 2018).

Furthermore, analyses of subsequent patenting activities indicate a moderate quantity-quality tradeoff in firms' patent output. Treated firms file more patents in response to the FSAP: Moving the average firm from the pre- to post-integration period results in a 25% higher likelihood of filing a patent. The increase in patent filings unfolds over time and follows the increased use of debt financing. However, on average, ex-ante constrained firms file patents of moderately lower market value and shift towards filing patents that protect relatively incremental, less technologically diverse inventions.

Heterogeneous treatment effects indicate the potential mechanisms behind the main findings. While treated firms increase the number of patents filed in response to the treatment irrespective of their pre-treatment patenting intensities, the FSAP leads to significantly higher patent quality for firms with low pre-treatment patenting intensities. This result indicates that financial resources are a key input for generating and commercializing innovation. Financing constraints may have previously muted these firms' patenting potential. In contrast, effects are reversed for firms with high ex-ante patenting intensity, and the FSAP (i.e., relaxed financing constraints) negatively affects patent quality. This finding supports empirical evidence about the adverse effects of policy-induced financial slack on inventive output (e.g., Almeida *et al.* 2021) and the quantity-quality tradeoff in patenting activities (de Rassenfosse 2013). Intuitively, ex-ante patenting-intensive firms are likely to have already realized their most promising projects, such that generating additional patents comes at the cost of adding patents of relatively lower quality to their portfolio. As such, for firms with high ex-ante patenting activities, additional financing may yield decreasing marginal returns to investments in inventive activities. Altogether, these results disclose new insights regarding the ambiguous findings on the relationship between financing constraints and inventive output.

Furthermore, the analyses show that additional funding induces firms to intensify their patenting activities. For instance, treated firms disproportionally spend more on patenting than on other operating expenses or capital investments comparing pre- and post-integration levels. At the same time, this increase in expenditures is proportional to the increased use of debt. This finding supports the empirical strategy by suggesting that firms use additional debt to invest in patenting.

Through a series of analyses, I mitigate potential concerns about the empirical strategy and emphasize the robustness of the main results. First, estimates verify that treated and control group firms follow parallel pre-trends. Second, analyses on the lagged effects support the empirical strategy and further suggest that (*de jure*) changes in the legal framework require some time to have quantifiable (*de facto*) effects. Third, results are strongest for firms more dependent on external financing, which is consistent with prior literature that finds firms with limited access to but high demand for external financing to depend disproportionally on fluctuations in the supply of debt financing (e.g., Becker and Ivashina 2014). Fourth, tests show that firms' lifecycle and growth dynamics are not better able to explain the main effects. Fifth, the results are robust to a placebo test that exploits the introduction of the Euro in 1999 as an alternative treatment event. This event is well-suited as a placebo setting since it constitutes a landmark of EU financial market integration, the macroeconomic developments are comparable to those in the original setting, but it should plausibly not affect the debt financing conditions of the treated sample. Indeed, the results of this exercise do not yield results comparable to the main findings.

The results of this study are important in that they add to our understanding of how policy-induced improvements in access to finance can affect inventive activities on the firm level. Mitigating financing constraints is an often favored target by policymakers and businesses in the attempt to spur firm-level innovation (Hottenrott and Peters 2012; Howell 2017; Chiappini *et al.* 2022). Hence, the analyses provide valuable insights into the consequences and potential mechanisms of policy-induced reductions in financing constraints for inventive activities, which is essential for designing effective policies both on the governmental and business level.

This study 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). In this context, a firm's lifecycle stage strongly affects which specific source of finance is most appropriate. Typically, for young, informationally opaque startups, external equity investments by venture capitalists appear most suited to fund their research and development activities (Casamatta 2003; Audretsch *et al.* 2020). However, recent findings highlight the relevance of external debt financing for inventive activities (Kerr and Nanda 2015; Mann 2018; Gill and Heller 2022), particularly the critical role of banks (Robb and Robinson 2014; Saidi and Žaldokas 2021; Ciaramella *et al.* 2022) even for young startups (Hochberg *et al.* 2018; Hirsch and Walz 2019). This study provides important findings on the role of debt financing for inventive activities in a new 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 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 bank 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). In contrast, I focus on financial market integration – a different form of market development that improves firms' access to debt financing. Prior literature shows that more integrated financial 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). Consistent with these conclusions, the present paper illustrates the positive effects of the FSAP on debt financing. Furthermore, it analyzes the subsequent implications on the patenting activities of affected firms, including a broad set of value-relevant characteristics and patent types. This approach provides a more comprehensive picture of how financial integration shapes inventive activities. The results deliver valuable insights regarding the potential limitations of investment 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. 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. Accordingly, the Commission developed the reform with four main targets: 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. To this end, it assigned EU member states to implement 42 legislative amendments over a period of six years. These amendments included 29 major pieces of legislation (27 EU Directives and two EU Regulations) in banking, capital markets, corporate law, payment systems, and corporate governance. Out of these amendments, seven banking-related directives are at the core of this analysis. To provide a specific example of one banking-related directive; the so-called Capital Requirements Directives allowed banks to reduce their regulatory capital requirements for claims on SMEs for a given level of risk. Therefore, the directives directly improved small firms' access to bank funding (Aubier 2007). Table A1 in Appendix A lists all FSAP Directives (Panel A) and sketches the timeline of the implementation of the seven banking-related directives (Panel B).

Overall, the FSAP had substantial effects on European financial market integration. Before adopting the legal changes, European markets were highly fragmented during the late 1990s, particularly in the banking market (e.g., Adam *et al.* 2002; Cabral *et al.* 2002). Throughout the 2000s, market integration surged due to the changes in law stipulated by the FSAP. For example, the FSAP had a direct effect in that it strongly enhanced business cycle synchronization (Kalemli-Özcan *et al.* 2013). More generally, other studies emphasize the importance of the FSAP for providing confidence in the reliability of financial regulation itself and that it represented a change in EU strategy away from market opening measures and towards common regulatory measures (Malcolm *et al.* 2009; Quaglia 2010; Meier 2019).

In the context of the EU banking market, Baele *et al.* 2004 conclude that financial integration could be "*considered quite advanced from a legal perspective*" (p. 522). Consistent with this, aggregate statistics show that this also holds on a *de facto* perspective; Panel A of Figure A1 (Appendix A) illustrates a surge of quantity- and price-based indicators of financial integration measuring loans by financial institutions to non-financial firms during the mid-2000s in Europe (see Hoffmann *et al.* 2020). The overall increase in financial integration during that time is predominantly due to enhanced integration in the banking market (see Panel B).

The nature of transposing EU Directives, such as those of the FSAP, into domestic legislation is advantageous for the empirical analysis, as it mitigates endogeneity concerns for several reasons. First, EU Directives are non-anticipatory, as they become effective on an individual country-specific basis after passing domestic legislation (Kalemli-Özcan *et al.* 2010, 2013). Typically, legal amendments on the EU level either do not result in changes in the law (recommendations and comments), or their implementation is strictly binding at a pre-defined date (regulations). Yet, these features do not apply to EU directives, which become effective on an individual country-specific basis after passing domestic legislation. This transposition process is notoriously slow, as it demands modifications of existing institutional structures, the removal of previous regulations, and oftentimes the renewal of agencies and infrastructure. Second, the FSAP Directives resemble political decisions made years in advance, so that implementation is unlikely to reflect market responses several years later (Christensen *et al.* 2016); The transposition deadlines for the FSAP were set in the late 1990s, and variations in domestic implementations occurred due to differences in aforementioned national legislative procedures. Third, implementing the directives is a domestic matter, whereas financial integration is a multilateral concept. As such, the Commission makes decisions on a supra-national level, rendering it unlikely for (mostly small) individual firms' actions to be related to country-specific initiatives (Schnabel and Seckinger 2019). This non-anticipatory feature of EU Directives applies even more so in this analysis because the FSAP Directives do not specifically target patenting activities by any means.[2]

[2] Summarizing these arguments suggests that for endogeneity to be of concern, countries would have to experience differentially timed local shocks, each promoting lawmakers to start transposition. These actions would have to be anticipatory and reflect firm-specific issues only relevant to specific firms. Eventually, FSAP directives will unlikely target medium-termed innovative activities many years in advance.

2.2 Financial integration and debt financing: mechanisms

The FSAP improved borrowing conditions for firms along two main dimensions. First, more integrated markets offer a more similar set of rules compared to a relatively less integrated market, lowering risk and information asymmetries. Aligned regulatory requirements induce reliability and transparency in the market and lower the costs of lenders to acquire relevant information or monitor debtors (Huberman 2001). If lenders pass through these cost improvements to borrowers, they eventually enhance access to debt financing. Indeed, Haselmann *et al.* (2009) show that access to bank loans improves for firms domiciled in previously less integrated markets, resulting in increased borrowing activity.

Second, financial integration changes the existing set of rules for all market participants. Such improvements in the legal setup allow a more efficient allocation of capital by reducing frictions in the financial intermediation process. For example, Liberti and Mian (2010) argue that an enhanced legal framework decreases collateral costs and thus mitigates borrowing constraints. Similarly, 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 suggest that financial market integration puts downward pressure on interest rates and eases accessing debt financing. Notably, these effects should be most pronounced for firms identified as ex-ante constrained, i.e., relatively small and young firms (Cetorelli and Strahan 2006; Brown *et al.* 2009).

2.3 Quantifying financial integration

To quantify financial integration, I use manually collected data on the effective country-specific transposition dates of the 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 directive. This way, the integration measure captures the multi-lateral nature of legal harmonization processes on supra-national levels instead of merely counting the implemented directives over time. The *de jure* integration measure is 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. The measurement approach accounts for the fact that financial integration is a multilateral concept by weighting the implementation of directives regarding the mutual implementation of other EU members.[3] Specifically, the indicator variable for the observed country c is multiplied by the fraction of all other EU-15 members j in which the respective directive is active. The FI-measure thus ranges between zero and one. Figure 1 displays the evolution of the time-varying and country-specific FI_{ct} measure as defined in Equation (1) over time. From 2001 until 2004, financial integration progresses relatively slowly compared to the second phase between 2004 and 2007.

- Insert Figure 1 here -

3 Data and Measurement

3.1 Data sources

The database 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 combine the two databases via a direct link in the ORBIS IP data. Further, I manually collect information on FSAP implementation dates and additional macro-level control variables.

I sample firms that filed at least one patent during the years 1999 to 2008.[4] Choosing these years allows to keep a broad time window around the implementation phase of the FSAP amendments and avoids confounding factors relevant to firms' financing behavior, such as the Financial Crisis (2009). Firms are allowed to enter and leave the database to avoid potential survivorship bias. Observations with zero or negative total assets, firms that cannot be categorized in industry classes, and firms from the financial or public sectors are excluded. To account for outliers, variables are winsorized at the 1 percent level. Further, the data samples ten countries, all of which are EU member states at the time of the FSAP drafting.[5]

The final sample consists of 118,724 firm-year observations (22,161 firms) from 10 countries and incorporates information on 703,378 patent applications. Panel A of Table 1 displays the distribution of observations across countries, which reflects the different proportions of these countries in most cases. One notable exception is Italy, for which the ORBIS data has only relatively low coverage during the years of observation. Panel B of Table 1 displays summary statistics on key financial variables. With the median founding year of 1990, firms are already well established at the onset of the FSAP implementation phase. In total, 3.9% of sample firms

[3] This can be illustrated considering a stylized, three-country scenario: if country A implements all FSAP Directives but country B and C do not implement any directives, no integration would be reached. If countries A and B adopt all respective laws but C does not, FI_{ct} is equal to 0.5 for countries A and B and 0 for country C. Only if all countries implement all directives at a given time does the measure equal 1.

[4] For the placebo analysis in Section 4.5, data is added on the three preceding years (i.e., 1996-1998).

[5] The FSAP was targeted at all 15 EU member states of the late 1990s. However, I exclude Austria, Greece, Luxembourg, Portugal, and Spain due to bad coverage in the financial data. Further, I do not consider firms from financial or service sectors, for which patenting is unlikely to be central to their business operations.

are listed corporations hence, reflecting that the actual European business landscape comprises predominantly small and medium-sized, well-established, and private firms.

- Insert Table 1 here -

3.2 Measuring inventions and descriptive statistics

A straightforward approach for measuring firms' patenting activities is to calculate the number of (annual) *patent applications*, which constitutes a quantitative measure of inventive output. As an essential complement, qualitative dimensions of firms' patenting activities are decisive, 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). The respective size of this step makes it more difficult to invent around a patent and lengthens the monopoly period for the patent holder. Patent offices thoroughly document detailed aspects of a patent's life for legal reasons, disclosing various facets of the underlying technology that can be leveraged to measure patent quality characteristics. Specifically, the empirical 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, because a larger number of citations reflects 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 total number of claims in an application by dividing them by backward citations (that is, references included in a patent description) to control for differences in the scope with respect to the prior art. Note that citations and claims are also indicative for the ex-post value of a patent (de Rassenfosse and Jaffe 2018).

To assess market value more directly, the empirical analyses consider the geographical scope in which a patent is protected and the number of years a patent is alive. These two dimensions reflect the market value of patents, and they are less related to technological features (see Hall *et al.* 2005).[6] As such, literature associates more valuable patents with a large international scope, the so-called *family size* (Harhoff *et al.* 2003; Hall *et al.* 2005). I count the number of jurisdictions in which patent protection is active. Further, a longer patent life requires a larger

[6] I deliberately do not use stock-market-related patenting measures, such as those introduced by Kogan *et al.* (2017), since the vast majority of sample firms are not listed on the stock market. While it is possible to approximate market values by matching on observable patent characteristics, the discrepancy between the reference group and sample firms questions such an approach.

number of annual renewals. Hence, *renewals* are a direct indicator of higher market value since perpetuating the protection of a patent is costly, particularly in Europe (de la Potterie 2010; Gill and Heller 2022). Firms' willingness to repeatedly incur these costs indicates the underlying patent value (Schankerman and Pakes 1986; Harhoff *et al.* 2009). To quantify this, I count the ex-post-determined frequency of patent renewals.

Furthermore, I distinguish between explorative and incremental patents to elicit more directly on different patent types. Explorative patents are characterized by riskier, large inventive steps and higher impact, whereas incremental patents involve relatively marginal improvements with no significant impact on follow-up inventions. Nevertheless, both types are value-relevant from a firm perspective (Beck *et al.* 2016). Explorative inventions have groundbreaking potential, possibly delivering high returns, whereas the successive but steady improvements of incremental inventions potentially deepen revenue-generating capacities of existing inventions (Henderson 1993). Appendix B provides further details on the patenting dimensions, their construction, and mutual relations.

Table 2 summarizes the definitions of all patenting dimensions and provides corresponding summary statistics. To map these patenting measures to firm-level financial data, I aggregate the individual patent-level information on a firm-year level that matches the panel structure of the financial information. 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%).[7] 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. Large countries (i.e., Germany, France, and Great Britain) are dominant in terms of the number of patents filed (see Table 1). Similarly, patenting activities cluster in specific sectors (see Table A2, Appendix A); 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.

- Insert Table 2 here -

[7]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 Identification strategy

Defining the model: To assess the impact of the FSAP on patenting activities, I employ a generalized difference-in-differences (DID) approach. The implementation of the seven banking-related directives marks a continuous treatment that affected firms across countries with different intensities over time. However, improved access to funding is unlikely to have a uniform effect across all firms. While generally all firms are exposed to the FSAP amendments, financial integration should relax financing constraints, especially for firms with insufficient internal funds and higher financing costs. Indeed, mitigating financing constraints should primarily affect firms with an unfulfilled demand for external debt, i.e., financially constrained firms (Brown *et al.* 2009; Becker and Ivashina 2014). Following this, I further utilize heterogeneity among sample firms regarding their propensity to respond to the legislative amendments to identify the effect of the FSAP on firms' debt financing and patenting activities. The identifying assumption is that financially constrained firms are disproportionally affected by the exogenous shift in market conditions.

I consider the S&A index as proposed in Hadlock and Pierce (2010) to quantify financial constraints. The index predicts constraints as a function of firm size and age. For the empirical setting, this is advantageous because it is applicable for a broad set of firms and, in particular, it can be calculated for private, small and medium-sized firms, i.e., the majority of sample firms.[8] For the classification of exposed firms (or treated and control groups), I use a relatively broad classification to acknowledge the lack of precision of standard measures of financing constraints (see Farre-Mensa and Ljungqvist 2016). Firms below the country-specific ex-ante median S&A value are considered financially constrained and vice versa. Further, firms are categorized based on their pre-integration levels of financing constraints to mitigate endogeneity concerns regarding variation in firm characteristics as soon as the integration process is initiated. Thus, the panel structure of the data enables controlling for unobserved heterogeneity across firms and for country-specific time trends, such as cyclical patterns in borrowing conditions. Formally, I estimate:

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

where the dependent variable Y_{ict} is either the financing activities or the inventive output of firm i, located in country c in period t. Financing activities are the logarithm of total debt, the long-term debt-to-asset ratio of firms, or the interest burden. Inventive output is one of the seven patent measures defined in Table 2. Table A3 (Appendix A) lists and defines all

[8] This is not the case for most other measures of financing constraints, such as the Kaplan-Zingales or the Whited-Wu index.

variables used in this paper. Regressions that use firm financial 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 outcome variables, such as patenting activities; it is important, as it accounts for the highly-skewed distribution and the issue of many zero observations in firm-level patenting activities (Cohn *et al.* 2022).[9] Irrespective of the estimation approach, I cluster standard errors by firms in the main specification – the results are not sensitive to clustering standard errors by the country- or country-industry level. $Treat_i$ is a dummy variable indicating the exposure to the treatment and equal to one for ex-ante financially constrained firms and zero otherwise. FI_{ct} is the country-specific, $dejure$ integration measure as defined in Equation (1). The coefficient of interest, β_1, captures the (local) average treatment effect on the exposed firms and displays the causal effect of the FSAP on firm-level financing and patenting activities. X_{it} is a vector of control variables as defined in Table A3 (Appendix A). The model includes firm- and country-year-fixed effects (β_i and β_{ct}, respectively) to control for unobserved firm-specific features and general changes in the macroeconomic conditions. Note that perfect multicollinearity would arise from including these fixed effects, which is why the single regressors of the interaction term are omitted in Equation (2).

Descriptive statistics suggest that the *de jure* increase in financial integration indeed had quantifiable (de facto) effects in terms of firm-level debt financing on an extensive and intensive margin. In the treatment group, about 9% of firms with no bank debt prior to the FSAP (i.e., in any year $FI < 0.2$) obtained bank debt by the end of the integration process (i.e., in any year $FI > 0.8$). This figure is significantly larger than for the control group (1.9%; p-value: 0.000). Moreover, treated firms exhibit higher use of debt on the intensive margin. The percentage change in bank loan amounts is significantly greater for treated versus control group firms, with 32.2% and 23.2%, respectively (p-value: 0.012).

Testing for parallel pre-trends: A series of tests show that ex-ante constrained and unconstrained firms follow a parallel trend regarding the main outcome variables before the treatment unfolds. Testing the pre-trends is crucial because financially constrained and unconstrained firms are likely to differ along several observable characteristics. However, a consistent DID estimation requires that treatment and comparison groups move in parallel trends prior to the treatment without necessarily being on comparable levels. First, I estimate a specification similar to Equation (2) but includes interactions of time dummies for each year prior to the FSAP with the $Treat$-indicator using a subsample of pre-treatment periods. Panel A of Figure A2 (Appendix

[9] Importantly, PPQML avoids the problems that arise when estimating linear regressions of the log of outcome plus 1, as commonly applied in many empirical studies on patenting outcomes. Most severely, OLS with log plus one variables produce estimates that lack meaningful interpretation and suffer from inherent biases, potentially causing estimates to have the wrong sign in expectation (see Cohn *et al.* 2022). Using PPQML, Equation (2) is formally described by: $E(Y_{ict}) = exp[\beta_1(FI_{ct} \times Treat_i) + \beta_2 X_{it} + \beta_i + \beta_{ct}] + \varepsilon_{ict}$.

A) plots respective coefficients and shows that non of them 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 an interaction of this trend with the $Treat$-dummy using the same subsample of pre-treatment periods. Finally, panel B of Figure A2 (Appendix A) displays the coefficients of regressions that use bank loans, patent filings, and patent quality variables as dependent variable. Consistent across specifications, coefficients are statistically insignificant, suggesting that firms from treatment and control groups move along similar paths.

4.2 Baseline results

4.2.1 The FSAP and debt financing

I begin by analyzing the effect of the FSAP Directives on firm-level debt financing activities. Panel A of Table 3 displays estimates on different variants of Equation (2) using the logarithm of bank loans (Columns I-III) and the bank debt-to-assets ratio (Columns IV-VI) as dependent variables. The regression displayed in Column I is similar to the main DID specification but does not include firm- or time-fixed effects such that the level variables of the DID estimator can be estimated. The estimator of the interaction term $FI \times Treat$ is positive, large, and significant at the one percent level. The coefficient suggests a disproportional increase in the use of debt comparing exposed firms relative to the control group after the adoption of the FSAP. The negative and highly significant coefficient on $Treat$ suggests that ex-ante constrained firms have less bank debt on average. Comparing the size of the estimate with the DID estimator (which is larger) indicates that the wedge between treated and control group firms vanishes as financial markets are integrated. Further, the positive coefficient on FI, suggests that the post-integration phase is generally associated with higher debt levels.

Column II displays estimates on the baseline specification and confirms the first findings from Column I. The DID estimator, β in Equation (2), is again highly significant and positive. The size of the coefficient implies an economically meaningful additional increase of bank loans of about 12% from pre- to post-FSAP implementation for ex-ante constrained firms relative to control group firms. To illustrate, an average amount of outstanding end-of-the-year bank debt of 120,000 Euros before the treatment implies an annual relative increase of approximately 13,500 Euros. Column III shows that increasing the threshold definition of financing constraints leads to even more pronounced effects, consistent with the identification strategy.[10] Columns IV and VI repeat the first three specifications but use the debt-to-asset ratio as an alternative specification of the dependent variable, yielding very similar results.

- Insert Table 3 here -

[10]Note that the average pre-integration amount of bank debt is about 280,000 Euros. Hence, on average, the coefficient (0.123) suggests a relative increase of 34,500 Euros per firm and year.

Panel B of Table 3 confirms the second proposition: the FSAP affected borrowing conditions. Columns I and II display regression estimates explaining the impact of the FSAP on firms' interest burden. In both specifications, the coefficients of the interaction term are negative and highly significant, showing that the FSAP is associated with disproportionally lower interest burdens for exposed firms. The effects are also economically significant. As such, the coefficient from the main specification in Column II suggests a 6% higher decrease in interest burden (equivalent to 0.6 percentage points) for the average treated firm compared to control group firms when moving from pre- to post-FSAP periods.[11]

Previous results show that the FSAP affects treated firms by raising their use of bank debt and lowering borrowing costs. However, this does not imply that these two outcomes are actually connected. Columns III and IV in Table 3 (Panel B) therefore reestimate the specification from Column II but estimated separately on split samples. Columns III and IV contain only firms with lower or higher average post-FSAP interest rates compared to their average pre-integration rates. Estimates in these columns show that the positive effect of the FSAP on bank debt is driven by firms that are observed to have relatively lower interest burdens after the FSAP. The DID coefficient is large, positive, and highly significant, while it is small and statistically insignificant for firms with no decrease in interest burden. Using triple interaction terms (Columns V and VI) provides equivalent results.

The analyses in Table 3 provide robust empirical evidence that the de jure measure of financial integration has quantifiable (i.e., de facto) effects on firms' debt financing activities. In particular, ex-ante financially constrained firms have higher levels of bank financing and lower levels of interest burden comparing changes in pre- and post-integration levels relative to ex-ante unconstrained firms. Further, increases in debt financing are mainly attributable to those firms with lower interest burdens, which is in line with the idea that financial market integration is accompanied by higher competition among banks. The downward pressure on interest rates raises firms' use of bank debt.

4.2.2 The FSAP and patenting

Next, I analyze 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 dependent variable. Column I displays a naive regression explaining firms' annual patent applications, including a set of control variables and the FI measure. The coefficient on the FI indicator is insignificant, suggesting that, on average, firms did not change their patent filing activities in response to the FSAP. Specifications in Columns II and III are equivalent to the first two columns of Table 3. Across specifications, the coefficient of the interaction term $FI \times Treat$ is positive, large, and significant at the one percent

[11]Specifically, with an average pre-treatment interest burden of treated firms is about 7.9%, the treatment effect is -0.0633 (= $-0.005/0.079$).

level, suggesting that the introduction of the FSAP has a positive disproportional effect on the number of patent filings of ex-ante financially constrained firms compared to the control group. The effect is economically significant in magnitude; the point estimate of 0.224 in Column III suggests that moving the average firm from the pre- to the post-integration period results in a 25% higher likelihood to file a patent.[12]

- Insert Table 4 here -

Moreover, regressions displayed in Columns III-VI test different transformations of the patenting variables to mitigate concerns that outliers or specific variable definitions might drive the results. The estimates show that results are stronger for firms that face higher financing constraints ex-ante (Column III); they are robust to using an alternative specification of the FI-indicator (Column IV) and alternative specifications of the dependent variable (Columns V and VI). These results show that the FSAP increased patent filing activities of firms that were ex-ante more financially constrained. Put differently, firms that disproportionally raised more debt throughout the financial integration process also filed disproportionally more patents.

Panel B of Table 4 illustrates the main findings of the baseline estimations, using the patent quality dimensions as dependent variables. It displays the point estimates of the interaction terms $FI \times Treat$ from the baseline regression equivalent to Column III in Panel A. In contrast to the effect on the number of patented inventions, the FSAP does not have an unambiguously positive effect on the technological quality and market value of patents (see the left graph of Panel B). In particular, there is a statistically significant positive effect on forward citations but not on the claims. This result suggests that patents' technological quality moderately increased or, at least, remained similar, disregarding the significant increase in patent filings from ex-ante financially constrained firms.

Further, the point estimates for family size and patent renewals are negative and statistically significant. However, compared to the effects on patent filings, the effects on the quality and market value are relatively small in economic terms. For example, the coefficient on family size suggests a 6% (= 0.246/4.006) relative decline throughout the FSAP adoption for ex-ante constrained firms relative to the control group.

Estimations explaining the effects of the FSAP on the generation of specific patent types corroborate with the estimates on patent quality and value (see the right graph of Panel B). As such, the average share of incremental or explorative patents among all filings is not affected by the FSAP. Again, this implies that ex-ante financially constrained firms filed patents of relatively similar types, disregarding the significant increase in patent filings. Decomposing these broader patent types into the two subclasses – high impact and technological diversity – mirrors the

[12]This is because 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. Note, β_1 refers to the respective point estimate obtained from estimating Equation (2).

previous results of a positive effect on forward citations and a negative effect on market value. 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.

Intuitively, the effects on average values of patenting dimensions may not fully reflect changes in the upper tail of the quality distribution. I repeat the main regressions on patent quality and market value characteristics to assess those changes using their firm-year maximum values (see Table A4 in Appendix A). The results are very similar, suggesting no disproportional changes in the upper bound of patent quality for ex-ante financially constrained firms. Equivalent to this, I conduct regressions on patent types similar to those in Panel B of Table 4 but use an indicator equal to one if a firm filed any patent that qualifies for respective categories in a given year. Here, results indicate an increase in both explorative and high-impact patents.[13]

Overall, the analyses show a more nuanced picture when considering changes in the quality and types of respective patents, compared to exclusively considering the number of patent filings. As such, patents' market value decreased, and firms' increasingly filed less technologically diverse patents. At the same time, the technological quality and the general occurrence of explorative and high-impact patents increased. Given the relatively small size of these effects and the lack of robustness, the results imply that firms generated more patents of relatively similar quality when comparing pre- and post-integration levels. In turn, these baseline results do not confirm the quantity-quality tradeoff in patenting but rather suggest a beneficial effect of relaxing financing constraints to enhance patenting activities.

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

Since financial market integration is a process that evolves over time, it is necessary to assess the timing of the effects thoroughly. As such, it takes time for the FSAP to affect firms' financing activities (Kalemli-Özcan *et al.* 2013; Christensen *et al.* 2016). Similarly, because of relatively high adjustment costs, firms adjust their research activities in response to a shift in funding with a time lag (Brown *et al.* 2009). To investigate this, I analyze the dynamic treatment effects of the implementation of the FSAP Directives on financing and patenting activities using an event study-like design:

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

where Y_{it} denotes the firm-level financing or patenting outcome in period t and $stage_{kc}$ refers to

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

the stage k of financial integration in country c.[14] I use two different specifications to define the integration phase. First, I measure the calender years relative to the country-specific first year in which the *de jure* FSAP measure is larger than zero, i.e., $FI > 0$. For illustration, the average FI-value for the years t+2, t+4, and t+6 are 0.29, 0.66, and 0.99, respectively. Second, I analyze the impact of the FSAP distinguishing different phases of the financial market integration. Here, the $stage_{kc}$ comprises four different stages that distinguish 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 cases, the reference period is the last period 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 these DID estimators 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 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 DID coefficients for regressions that use patent filings as dependent variables increase only in year t+3 and turn significant as of the years t+5. These results support the notion that firms adjust patenting activities in response to enhanced use of bank debt.

- 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 unfolds already in the early integration phase. In contrast, for patent filings, the positive effect only unfolds in the later phases of financial integration. Consistent with the empirical strategy, the results on the dynamic effects of the FSAP show that financial integration first affects firms' debt financing activities and only leads to increased patent filing activities in a lagged response.

4.4 Heterogeneous treatment effects

Dependence on external financing: Firms with limited access to financial resources but relatively high demand for financing are prone to fluctuations in the supply of external debt financing (e.g., Becker and Ivashina 2014). Hence, firms with a high ex-ante dependence on external financing among treated firms should respond stronger to the implementation of the FSAP. To study this, I exploit cross-sectional heterogeneity regarding firms' demand for ex-

[14] 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).

ternal financing. I follow the literature and measure firms' dependence on external financing using the Rajan-Zingales (RZ) index (see Rajan and Zingales 1998). The measure essentially relates the free cash flow of firms to their expenditures; firms with relatively higher expenditures are expected to be more dependent on external financing.[15] Firms are assumed to be ex-ante dependent on external financing if their pre-FSAP (i.e., $FI < 0.2$) index score is above the median. Consistent with the empirical strategy, the effects of the FSAP should be particularly pronounced for firms with above-median RZ index scores.

Panel A of Table 5 shows estimates testing this proposition by re-estimating the baseline regressions explaining both debt financing (Columns I-III) and patenting filings (Columns IV-VI). I split the sample to separately estimate the baseline specification for firms that are dependent on external financing (Columns I and IV) or not (Columns II and V). For both dependent variables, results for firms with low ex-ante dependence on external financing are relatively statistically insignificant and relatively small (0.022 and 0.095, respectively) compared to firms with high dependence on financing (0.152 and 0.329, respectively). The coefficient for the interaction term $FI \times Treat$ is significant at the one percent level in the latter case. Using a triple difference estimation confirms these results; Here, I interact the DID-estimator with a $DepFin$ indicator that equals one if a firm is ex-ante dependent on external finance and zero otherwise. Including this regressor, the coefficient of the DID-estimator turns insignificant, while the coefficient on the triple interaction term is large, positive, and highly significant. 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 -

Firm growth dynamics: Next, I address a natural concern about the empirical strategy, which is that firms' lifecycle dynamics may drive the main results effects. By definition, the average ex-ante financially constrained firm is smaller and younger than an unconstrained firm. While all previous estimations control for firm size and other firm-specific but time-invariant 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 estimate and compare the effects of the FSAP for firms with high growth rates to those in the treatment group in the baseline specification. As such, Panel B of Table 5 displays estimations that are specified similar to the baseline regression in Equation (2) but add an interaction term of the financial integration measure (FI) with a dummy variable that flags high-growth firms ($Growth^{\text{high}}$). For robustness, the tests use three distinct definitions for high growth, all measured during the pre-treatment period. That is, high-growth firms have

[15] Specifically, the RZ index defines firms' demand for external financing and is computed by: $RZ = (capex - cf)/capex$ with firms investments (capex) related to their cash flows (cf). I compute this measure on the pre-treatment period (i.e., $FI < 0.2$).

above-median levels of growth in terms of total assets, total employment, and wage payments. Coefficients measure the disproportional effect of the FSAP on high-growth firms. Adding these interaction terms does not affect the sign, size, or significance of the interaction term $FI \times Treat$, which remains positive, economically sizable, and highly significant. In contrast, the coefficients on the interaction terms $FI \times Growth^{\text{high}}$ 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 dependent variable.

Hence, the main results remain unchanged when considering differences in firm size and growth dynamics. This finding is important since these variables are key determinants for patenting activities across firms and within firms over time. The above results mitigate concerns that firm growth patterns and not financial market integration trigger the observed changes in financing and patenting activities.

4.5 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. In order to address these concerns, I repeat the baseline analysis using an alternative sample time frame, which is comparable with respect to macroeconomic conditions and financial integration but is not associated with improving access to bank 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 in 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); a notion also supported by aggregate statistics (see Figure A1 in Appendix A). More specifically, Haselmann and Herwartz (2010) find that the Euro did not effectively reduce information asymmetries between firms and banks. 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, firms are classified as treated if the average pre-Euro S&A score is above the respective sample median. All other variables are computed as in the baseline setting except for the treatment variable. For completeness, the analyses use two placebo treatment variables that acknowledge the difference in the implementation timing 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 reflects the inauguration of the Euro as a one-time event. Second, an alternative 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. Using the two approaches mitigates concerns that the actual specification of the placebo treatment variable biases results.

- Insert Table 6 here -

Table 6 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 but use the placebo setting and include only firms from countries that adopted the Euro as the official currency. The coefficients of the interaction term $FI^{\text{placebo}} \times Treat$ are small and lack statistical significance. In particular, the DID coefficient in Column II is very small, negative, and insignificant. This result is robust to using a sample with firms from all countries in the original sample, i.e., irrespective of whether they adopted the Euro (Columns III and V). Using the continuous placebo-treatment variable that mimics the adoption of the FSAP Directives also yields very similar results (Columns IV and V). These results verify that the introduction of the single currency in 1999 did not have a comparable effect on the retail 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.[16] Again, the coefficients of the interaction term are positive but relatively small and insignificant. Hence, the placebo analysis shows 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 further strengthen the validity of the empirical strategy.

[16] Table A5 (Appendix A) displays estimates using patent quality and market value measures as dependent variables. Again, estimations are statistically insignificant across specifications.

5 On the empirical mechanisms

5.1 Did the FSAP affect firms' patenting intensities?

This section documents the potential mechanisms behind the main results. To this end, I start by analyzing whether the FSAP and the higher use of debt financing can be attributed to changes in firms' patenting intensity in terms of shifts in investment strategies. These analyses use a subsample of firms for which data on firm-level annual patenting expenses from Gill and Heller (2022) is available.[17] Patenting expenses include application, grant, and renewal fees. These costs increase over time and with the number of designated jurisdictions where protection is sought. Hence, measuring patenting expenses moves beyond adding up filing fees, which would be merely a linear transformation of the number of patent filings. These costs are particularly relevant in the context of this study since administrative fees are relatively high in Europe (de la Potterie 2010). Furthermore, using patenting expenditures allows for making better inferences about changes in the operating strategies of firms as compared to analyzing the size of the active patent portfolio over time.

Panel A of Table 7 displays statistics on firms' annual patenting expenditures. The average firm spends about 20,000 Euros on patenting activities each year. However, this number varies greatly, ranging from zero costs to more than 2.5 million Euros annually. Over the course of the financial integration period during the 2000s, ex-ante financially constrained firms significantly raised patenting expenses. In order to measure firms' patenting intensity, I compute firms' annual expenditures as ratios to other accounting variables, such as total assets, total expenditures, operating expenditures, and capital investments. The variable lists in Table A3 (Appendix A) include a more detailed description of these variables. On average, patenting fees only constitute a small share of total expenses. Yet, similar to the highly skewed distribution in patent values, the share of patenting expenses to other expenses can also be very high.

- Insert Table 7 here -

I analyze whether the FSAP affected firms' patenting expenditures by estimating the baseline specification of the set of patent expenditure ratios defined above. Panel B of Table 7 displays the DID estimation results. Column I uses firms' total asset-to-patent expenditure ratio as dependent variable, which can be interpreted as an indicator of the patent intensity of a firm. The coefficient on the interaction term $FI \times Treat$ 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 Directives compared to unconstrained firms by about 60% (with 0.006 as the mean dependent variable).

[17]Studying patenting expenses instead of research and development (R&D) expenses is beneficial, due to the limited data availability of R&D data for relatively small, private firms, which constitute the majority of the original sample. Indeed, patent expenditure information is available for about 20% of the original sample, while R&D data is only available for a selection of large firms that constitute about 3% of observations. Figure A4 (Appendix A) illustrates the strong positive relationship between expenditures on R&D and patent fees.

Columns II-IV use a set of expenditure ratios as dependent variables that measure the sum of patenting expenses relative to other expenditures. These ratios capture the relative weight of patent-related expenses and, thus, their importance in the cost management strategy of firms. The coefficient on the DID interaction in Column II is positive and significant at the five percent level. The size of the coefficient suggests a relative increase in patent expenditures as a fraction of total expenditures by a factor of 33% (= 0.004/0.012). Next, I decompose these expenditures into operating expenses and capital expenses. Estimates in Columns III and IV show that the increased weight on patenting expenses is mainly attributable to a relative increase in total operating expenses. Here, the coefficient is positive, highly significant, and suggests a relative increase to the mean by 67% (= 0.006/0.009). For the patent expenses-to-capital expenses ratio, the coefficient is also positive but only significant at the ten percent level. It suggests a more modest increase to the mean of 52% (= 0.011/0.021). This differential effect may reflect that patenting expenses resemble operating expenses rather than capital expenses, i.e., investments into tangible assets.

Estimates in Columns V and VI provide further details on the relationship of patent expenses to the increased use of debt. Specifically, I use firms' patenting expenditure-to-debt ratios as dependent variables. The coefficients on the interaction terms $FI \times Treat$ are positive but insignificant using both bank debt and total debt as denominator for the respective patent expenditure ratio. These results show that the increase in patenting expenses (and patenting intensity) is proportional to the increase in debt. Thus, the raised amount of debt is large enough to cover the additional patenting costs associated with the increase in patenting intensity. In sum, this section shows that treated firms intensify their patenting activities disproportionally; the increased level of debt may at least partially finance this shift.

5.2 On the disciplining effect of financial constraints

The baseline results provide a mixed picture of the patent quality-related outcomes for the average treated firm. However, average treatment effects may hide meaningful heterogeneous responses to the treatment that further help to explain the relationship between improved access to financial resources and firms' patenting activities. Therefore, this subsection explores cross-sectional heterogeneity regarding firms' ex-ante patenting intensity to understand the quantity-quality mechanisms better. Further, the analysis sheds light on the disciplining effect of financing constraints in the context of firms' patenting activities.

A priori, it is not clear which type of firms, incumbents or entrants, are more prone to the disciplining effect. If only insufficient resources are available, financially constrained firms have to forgo some promising research projects. This constraint induces firms to rationally implement the projects of highest expected value first (see e.g., Hottenrott and Peters 2012). Alleviating these constraints might cause firms to work on inventive projects of relatively lower quality out of their set of alternatives as long as these projects have a positive net present value. As such, for firms that already implemented their most valuable projects, enlarging their patent portfolio comes at the cost of adding patents of relatively lower quality to their portfolio.The decline in patent quality results from decreasing returns to investment in inventive activities (Lokshin *et al.* 2008). Plausibly, the effect of decreasing returns to investment should be observed particularly for firms with a relatively high patenting intensity ex-ante. However, it is possible that the expansion of relatively less patenting-intensive firms might cause patent quality to decrease too. As such, high opportunity costs of patenting might have previously crowded out firms of relatively low potential, i.e., as proposed by de Rassenfosse (2013). Relaxing financing constraints lowers the opportunity costs and thus may induce respective firms to file more patents, even though they are of lower average quality than the pool of existing patents. These rationales illustrate that is essentially an empirical question, what types of firms are more prone to the disciplining effect of financing constraints.

To answer this question, I distinguish firms with relatively high and low ex-ante patenting intensity. Consistent with Section 5.1, I consider firms' patenting expenditures to determine their patenting intensity. This approach is beneficial as it captures firms' actively held patent portfolios, disregarding a potential absence of patent filings. Specifically, I classify firms as high patenting-intensive once they have above median patenting expenses for the country-specific years in which $FI < 0.2$, and vice versa.

The effects of the FSAP on patent filing activities, i.e., the quantity dimension of patenting, are very similar for firms with high and low ex-ante patenting intensities. As such, Panel A of Figure 3 recasts Figure 2 but estimates the timing of the FSAP effects separately, distinguishing firms' patenting intensities prior to the financial integration. Both firm types 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 firms' propensity to adjust the number of patents produced to the improved access to external debt financing.

- Insert Figure 3 here -

Next, I analyze the effects of the FSAP on patent quality-related outcomes and distinguish firms with high and low ex-ante patenting intensities. Panel B of Figure 3 summarizes the findings graphically. Along several dimensions, the effects are fairly homogenous, such as the market value patenting dimensions. However, there are several notable differences. For the subsample of ex-ante low patenting intensive firms, the coefficients on forward citations and high-impact patents are positive and statistically significant. Firms with little prior patenting experience exhibit a disproportionally positive effect along these dimensions. Hence, the positive effects indicate an enhancing effect of improving access to external financing for firms with little prior patenting activities. These findings are consistent with the idea that financial resources are key input factors for enabling the initial commercialization of innovation (Nanda and Rhodes-Kropf 2017). Better access to funding appears to release the previously unexploited inventive potential of some financially constrained firms.

In contrast, for the subsample of firms with high ex-ante patenting intensity, the coefficients on incremental patents (positive) and technological diversity (negative) are statistically significant. In this case, the disciplining effect of financing constraints might have played a role. The improved access to finance induced these firms to file more patents. However, firms added patents of a relatively more incremental nature to their existing portfolio. This aspect supports the hypothesis that financial constraints serve as a disciplining device for this subset of firms before the treatment.

Overall, these analyses uncover two main insights. First, firms with ex-ante high patenting intensity increase their propensity to file patents that protect incremental and less technologically diversified inventions. This result corroborates the notion of the patent paradox, which states that increased patenting does not imply increased innovation (e.g., Hall and Ziedonis 2001; Klein 2020). Second, the effect of decreasing returns on investment in inventive activities can only partly explain the main effects, i.e., the modest average decline in patent quality. Indeed, the removal of financing constraints has beneficiary outcomes for firms that might have not yet exhausted their inventive capacity: For relatively less patenting-intensive firms, the FSAP has both a positive effect on the quantity and the quality of patenting activities while enhancing their propensity to file more explorative, high-impact, and highly cited patents. These findings are consistent with the idea that financial resources are key input factors for enabling the initial commercialization of inventions (Nanda and Rhodes-Kropf 2017). Better access to funding may have released previously unexploited inventive potential embodied in some financially constrained firms.[18]

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 subsequent impact on firms' financing and inventive activities. Investigating the implications of policy-induced improvements in firms' access to external financing is vital since financial resources are a key determinant of innovative activities and, thus, economic growth. Consistent with this idea, many policy initiatives aim to improve access to finance, particularly for more vulnerable, financially constrained firms. Yet, at the same time, there is ample evidence that relaxing financing constraints can negatively affect firms' inventive efficiency. In particular, prior research has identified a potential quantity-quality tradeoff in the context of patenting. This study aims to improve

[18]Notwithstanding, the differences in the coefficients across high and low ex-ante patenting intensive firms are relatively small. Hence, this discussion has to be evaluated with caution.

our understanding of the (unintended and ex-ante ambiguous) implications of policy initiatives intended to relax financing constraints, such as the FSAP, on firms' inventive activities.

The empirical analyses provide a nuanced picture of the effects of the FSAP, using a large-scale sample that includes primarily small and medium-sized firms across multiple European countries and industries. First, the FSAP caused firms to raise their use of debt of previously financially constrained firms to a (statistically and economically) significant degree. As one likely channel, the changes in law fostered debt financing by lowering the costs of obtaining debt. 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 period results in a 25% higher likelihood of filing a patent. Third, the increase in patent filings is, on average, not accompanied by a change in patent quality, implying that the average firm that benefits from better access to debt financing does not file patents of worse patent quality. However, along some dimensions, such as the market value of patents, results suggest a modest decline. Fourth, in response to the FSAP, ex-ante financially constrained firms intensify their patenting activities by disproportionally spending more on patenting. Fifth, distinguishing firms according to their pre-integration patenting intensity shows that previously low patenting-intensive firms 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 underline the importance 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. Different outcomes regarding the quantity and quality of patents 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

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

Panel B: Descriptive statistics on firm-level data

Variable	Definition (Orbis code)	Obs.	Mean	SD	Q25	Q50	Q75
Firm size	$= log(\texttt{toas})$	118,724	8.831	2.518	7.124	8.855	10.495
Tangibility	$= \texttt{tfas}/\texttt{toas}$	118,724	0.204	0.210	0.048	0.135	0.294
Cash-flow ratio	$= \texttt{cf}/\texttt{toas}$	118,724	0.065	0.188	0.028	0.086	0.146
Profitability (RoA)	$= \texttt{pl}/\texttt{toas}$	118,724	0.061	0.138	0.003	0.048	0.111
Bank debt (log.)	$= log(1 + \texttt{loan} + \texttt{cred})$	118,724	6.778	2.999	4.997	7.097	8.839
Bank loan ratio	$= (\texttt{loan} + \texttt{cred})/\texttt{toas}$	118,724	0.237	0.207	0.085	0.180	0.337
Interest rate	$= \frac{\texttt{interest}}{(\texttt{liab}_t + \texttt{liab}_{t-1})/2}$	91,672	0.076	0.091	0.026	0.055	0.092

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. Panel B displays summary statistics on firm financial information from ORBIS. The first four variables are the firm-level controls included in each regression, and the last three variables are the primary dependent variables regarding firms' financing activities. The second column contains the variable definition expressed using the original ORBIS variable tags. All variables are defined in Table A3 (Appendix A).

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 introduced in Section 3.2. 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. For more details on the computation of the patenting variables and more elaborate definitions, see Table A3 (Appendix A) and Appendix B, respectively.

Table 3: Financial integration and debt financing

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

Dependent variable:	Bank debt (log.)				Debt-to-asset ratio			
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
FI × Treat	0.237***	0.118***	0.123***	0.091***	0.025***	0.011***	0.016***	0.008***
	(0.032)	(0.027)	(0.038)	(0.020)	(0.004)	(0.004)	(0.005)	(0.003)
FI	0.864***				0.048***			
	(0.071)				(0.006)			
Treat	-0.170***				-0.033***			
	(0.029)				(0.004)			
Exposure threshold:	Q50	Q50	Q75	Q50	Q50	Q50	Q75	Q50
FI definition:	cont.	cont.	cont.	dummy	cont.	cont.	cont.	dummy
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	No	No	No	Yes	No	No	No
Firm-FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Country-Year-FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
R^2	0.69	0.90	0.90	0.90	0.11	0.76	0.76	0.76
Observations	115,906	115,906	115,906	115,906	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 × Treat	-0.007***	-0.005***	0.148***	0.037	0.066	0.030
	(0.003)	(0.002)	(0.042)	(0.045)	(0.049)	(0.045)
Treat	-0.023***				-0.173***	
	(0.003)				(0.042)	
FI	0.016***				0.273***	
	(0.002)				(0.064)	
FI × Treat					-0.039	
					(0.058)	
Beneficiary					-0.066**	
					(0.032)	
FI × Beneficiary					0.042	0.040
					(0.035)	(0.032)
FI × Treat × Beneficiary					0.151**	0.122**
					(0.067)	(0.061)
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

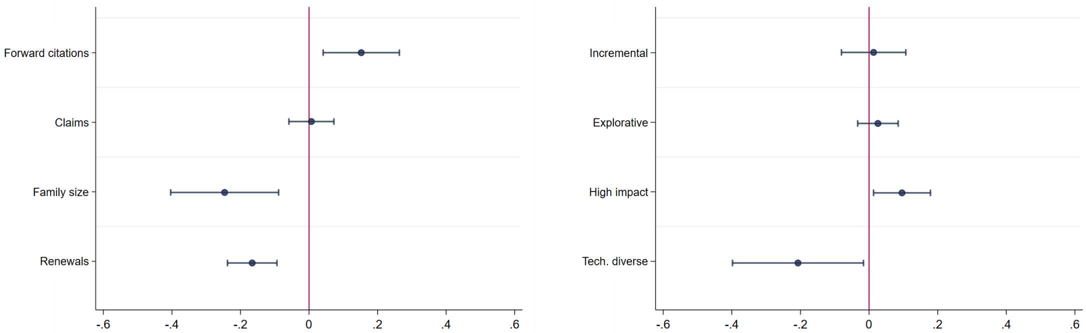
Notes: Panel A presents the DID coefficient estimates from fixed effects panel regressions explaining the effect of financial integration on the use of bank loans. The regressions are different variants of the baseline specification, as defined in Equation (2). The dependent variables are the logarithm of bank loans (Columns I-IV) and bank loans-to-asset ratios (Columns V-VIII), as specified in Table A3 (Appendix A). Column I is similar to the baseline specification but excludes firm- and year-fixed effects. The regression includes industry-fixed effects and country-level macroeconomic controls. Column II estimates the baseline specification. Columns III and IV use different definitions of the DID-estimator components. In Column III, the $Treat$-dummy equals one for all firms in the top *quartile* of the ex-ante financing constrained distribution. In Column IV, the FI-dummy is a binary indicator equal to one for all years after 2004, i.e., in which the original FI variable is above 0.5. Columns V-VIII repeat the specifications of the first four columns but use the bank debt-to-asset ratio as dependent variable. Panel B presents estimates from regressions explaining the impact of financial integration on firms' interest burden and the use of banks according to whether firms benefit from integration by having lower post- compared to pre-integration interest burden. Columns I and II repeat the first two columns from Panel A but use firms' interest burden as dependent variable. Columns III-VI use the logarithm of bank debt as dependent variable. Here, Columns III and IV display estimates on regressions similar to Column II of Panel A but estimated on sample splits using firms that face lower interest burdens comparing post- to pre-treatment periods and those facing 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 FSAP and patent filings

Dependent variable:	Patent filings						
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
FI × Treat		0.176***	0.224***	0.273***	0.151***	0.186***	0.066**
		(0.048)	(0.047)	(0.050)	(0.033)	(0.046)	(0.032)
Treat		0.344***					
		(0.050)					
FI	-0.078	-0.212**					
	(0.086)	(0.088)					
Model specification:	-	-	-	Q75	FI-Dummy	Normalized	log.
Additional controls:							
Firm level	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro level	Yes	Yes	No	No	No	No	No
Industry-FE	Yes	Yes	No	No	No	No	No
Firm-FE	No	No	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	No	No	Yes	Yes	Yes	Yes	Yes
Observations	115,906	115,906	115,906	115,906	115,906	115,906	115,906

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



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-IV are specified as in Columns I-IV of Panel A in Table 3; only here, the dependent variable is patent filings. As such, Column III is the baseline regression defined in Equation (2). Column V 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., $P^{\text{norm.}} = (\text{filings}_{it} / \max.\ \text{filings}_{cnt})$ for firm i in country c, industry n, and time t. Column VII uses the logarithm of patent filings as dependent variable, and the estimation method is an OLS. 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. Panel B plot coefficients of the DID estimators deployed in fixed effects panel regressions equivalent to Column III in Panel A. Here, the outcome variables are the different patenting dimensions regarding patent quality and value (left figure) and patent type (right figure). These variables are defined in Table 2. Whiskers span the 95 percent confidence intervals.

Table 5: Heterogeneous treatment effects and robustness tests

Panel A: Dependence on external financing and the effects of the FSAP

Dependent variable:	Bank loans			Patent filings		
Dependence on external financing (*DepFin*):	Low	High	All	Low	High	All
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × Treat	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 × *DepFin*			0.019			-0.114*
			(0.030)			(0.068)
FI × Treat × *DepFin*			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 loans			Patent filings		
$\text{Growth}^{\text{high}}$ definition:	Assets	Employment	Staffing costs	Assets	Employment	Staffing costs
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × $\text{Growth}^{\text{high}}$	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 × Treat	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 regressions are similar to the baseline specifications in Tables 3 and 4. 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 dependence on external financing. Financial dependence is measured by firms' RZ score, as defined in Table A3 (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 $DepFin$ with the DID estimator and the FI measure. $DepFin$ is a dummy variable equal to one for all firms with high ex-ante dependence on financing ($DepFin$) and zero otherwise. The base variable and the interaction of $DepFin \times Treat$ 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 $FI \times \text{Growth}^{\text{high}}$; $\text{Growth}^{\text{high}}$ 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: Placebo regressions: analysis on the Euro introduction in 1999

Dep. variables:	Bank debt					Patent filings	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
$FI^{\text{placebo}} \times$ Treat	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 7: Financial integration and patenting expenditures

Panel A: Variable definitions and descriptive statistics

Variable	Definition	Obs.	Mean	SD	Min.	Max.
$PatExp$	Sum of total annual payments on patenting fees obtained from Gill and Heller (2022)	18,911	19,775	97,748	0	2,512,505
	Out of which $PatExp > 0$	12,290	30,429	119,910	26	2,512,505
$PatExp$-to-assets	$PatExp$ over total assets	18,911	0.006	0.024	0	0.179
$PatExp$-to-expenses	$PatExp$ over total annual expenses	16,809	0.012	0.058	0	0.459
$PatExp$-to-opex	$PatExp$ over total operating expenses	9,180	0.009	0.027	0	0.349
$PatExp$-to-capex	$PatExp$ over total capital expenses	8,053	0.021	0.094	0	0.711
$PatExp$-to-total-debt	$PatExp$ over total debt	16,843	0.028	0.134	0	1.090
$PatExp$-to-bank-debt	$PatExp$ over total bank debt	18,220	0.053	0.250	0	2.026

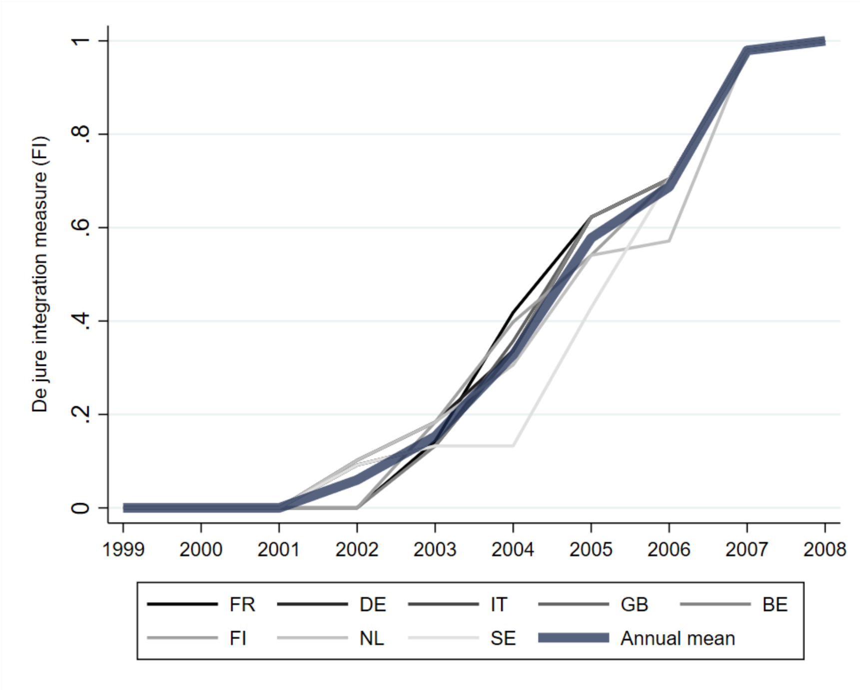
Panel B: Regression estimates explaining changes in patent expenditure ratios

Dependent variable:	Patenting expenditures ratios					
Denominator:	Assets	Total expenses	Opex	Capex	Total debt	Bank debt
	(I)	(II)	(III)	(IV)	(V)	(VI)
FI × Treat	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 defines different variants of the patent expenditure ratios and displays summary statistics on them. 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:

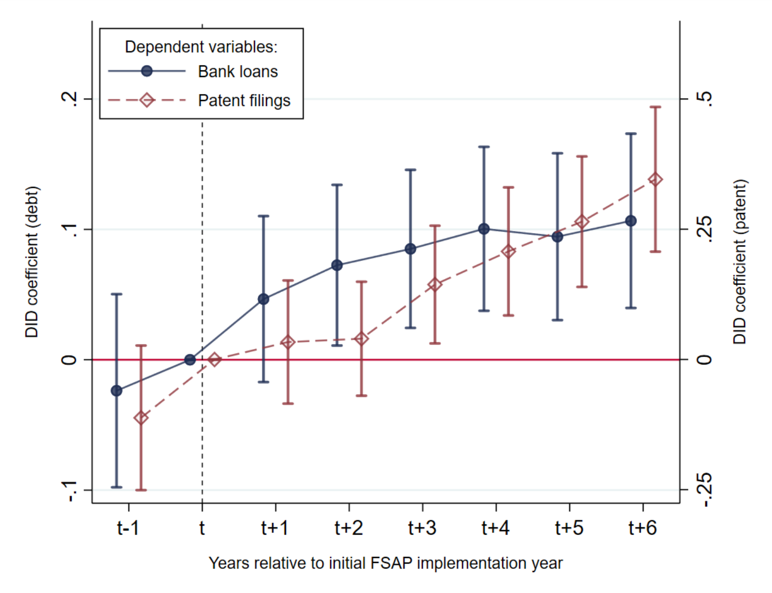
Figure 1: Financial market integration measure based on FSAP Directives (1999-2008)



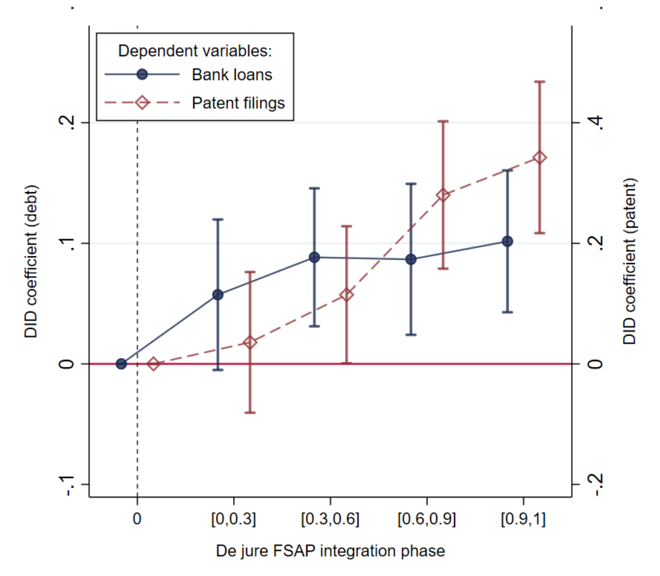
Notes: This figure plots the *de jure* integration measure, FI, as defined in Equation (1) over the sample time frame. Each thin line represents one sample country, and the thick line plots the average FI value per year. The values range between 0 and 1, indicating low (= 0) and high (= 1) multilateral adoption of FSAP Directives, i.e., financial market integration.

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



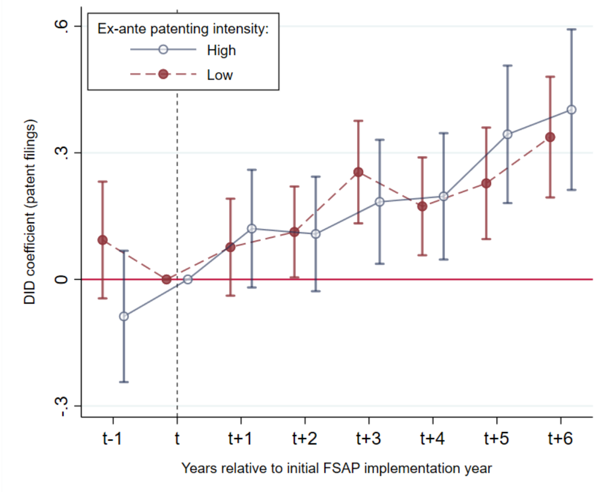
Panel B: DID coefficients for different FSAP phases



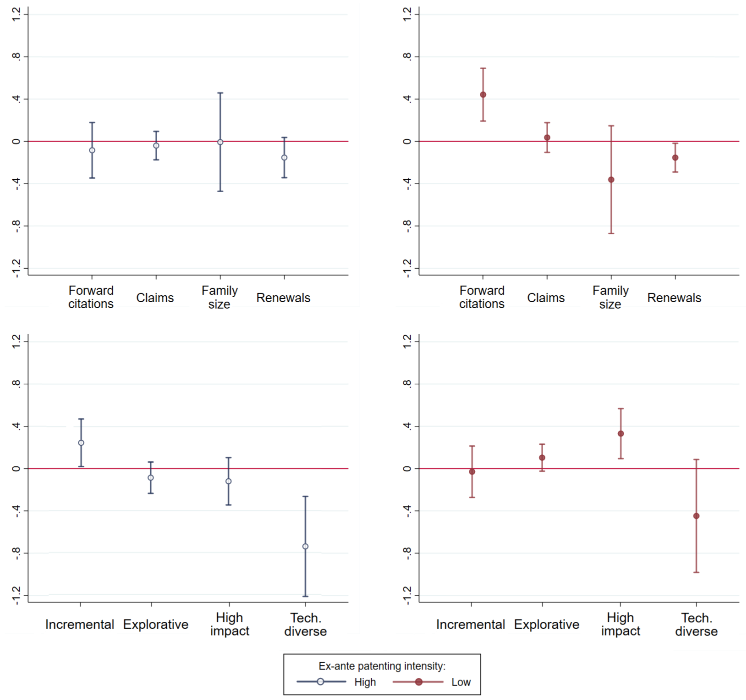
Notes: The figures decompose the baseline effect regarding the timing of the effects. The analysis is identical to Columns II and III of Tables 3 and 4, except that the $Treat$ indicator is replaced with a full set of event-year dummies. In Panel A, the periods refer to the calendar years relative to the country-specific last year in which non of the FSAP Directives was adopted, i.e., in which $FI = 0$. The corresponding 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 four periods of integration: the early phase, the intermediate phase, the late phase, and the fully integrated phase; the corresponding FI values are displayed in the axis labels of the chart. Here, the pre-treatment period is used as reference period. Whiskers span the 90 percent confidence intervals.

Figure 3: Heterogeneous effects across different levels of ex-ante patenting intensities

Panel A: Patent filing activities for high and low ex-ante patenting intensities



Panel B: Heterogeneous effects across patent quality and patent types



Notes: Panel A is identical to Panel A of Figure 2, using the annual number of patent filings as dependent variable, 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 is identical to Panel B of Table 4, except that 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):

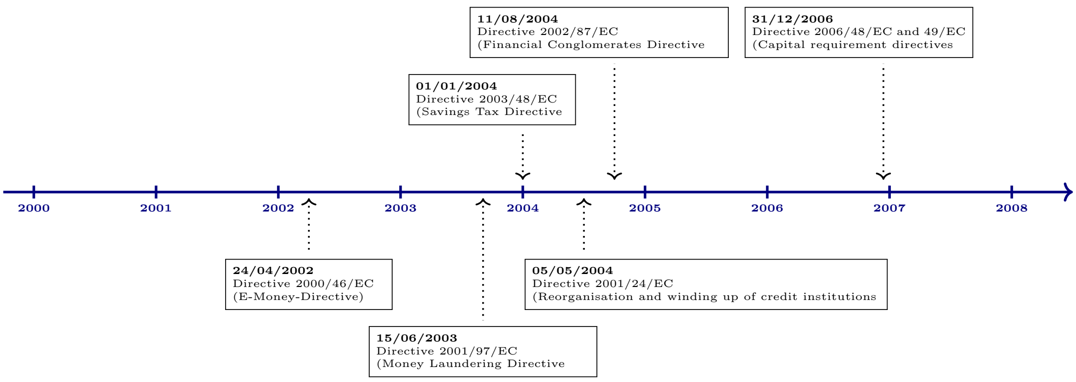
Appendix A : Tables and Figures of the Appendix

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

Panel A: List of Directives

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

Panel B: Time schedule of 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). Transposition dates refer to the intended implementation deadline set by the EU. However, actual transposition dates significantly vary between countries. Therefore, country-specific implementation dates are not reported but can be provided by the author upon request. Panel B illustrates the timeline of the banking-related FSAP measures graphically.

Table A2: 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 A3: List of variables

DID estimators:	
FI	*De jure* measure of financial integration, as defined in Equation (1).
Treat	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, and 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.
$DepFin$	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.
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`).
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*	Return on assets, i.e., total end-of-year profits (`pl`) over total assets (`toas`); truncated at 1 percent level.
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.
Patenting variables:	
Patent filings	Total count of priority patent filings at any of the EPC country (jurisdiction) of a firm in a given year.
Forward citations	The average number of all citations received within the first seven years after filing of patents filed by a firm in a given year; citations are determined ex post (quality indicator).

(*continued on next page*)

Table A3: *continued*

Patenting variables: *continued*	
Claims	The average number of claims included in patents filed by a firm in a given year; claims define individual properties, i.e., the subject-matter, that are protected by a patent. To normalize values, claims are divided by the number of backward citations (quality indicator).
Family size	The average of the (maximum) number of jurisdictions in which any patent filed by a firm in a given year is protected; the family size is determined ex post (value indicator).
Renewals	The average number of total renewals of all patents filed by a firm in a given year; renewals are determined ex post (value indicator).
Incremental	Average number of incremental patents among all patents filed by a firm in a given year; incremental patents do *not* fulfill the two criteria of being a patent of high quality patent nor a broad scope patent (defined below and detailed in Appendix B).
Explorative	Average number of explorative patents among all patents filed by a firm in a given year; explorative patents fulfill the two criteria of being a patent of high quality patent and having a broad scope (defined below and detailed in Appendix B).
High-impact	Average number of high-impact patents among all patents filed by a firm in a given year; 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	Average number of technologically diverse patents among all patents filed by a firm in a given year; 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.
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 *PatExp* to total assets (Orbis, `toas`).
PatExp-to-expenses	Ratio of *PatExp* 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 *PatExp* to total operating expenses (`cost` and `oope`).
PatExp-to-capex	Ratio of *PatExp* to total capital expenditures (`exp_mat`).
PatExp-to-total-debt	Ratio of *PatExp* to total liabilities (`culi` and `ncli`).
PatExp-to-bank-debt	Ratio of *PatExp* to total bank debt (`loan` plus `cred`).

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. Appendix B contains further details on the patenting variables.

Table A4: Financial integration and patent quality measures: main specifications and maximum values

Patenting dimensions:	Technological quality				Market value			
Dependent variables:	Forward citations		Claims		Family size		Renewals	
	Avg.	*Max.*	*Avg.*	*Max.*	*Avg.*	*Max.*	*Avg.*	*Max.*
	(Ia)	(Ib)	(IIa)	(IIb)	(IIIa)	(IIIb)	(IVa)	(IVb)
FI × Treat	0.152**	0.111**	0.007	0.271	-0.246**	-0.318**	-0.126***	-0.836***
	(0.068)	(0.056)	(0.040)	(0.261)	(0.096)	(0.132)	(0.034)	(0.211)
Patenting dimensions:	Patent types							
Dependent variables:	Incremental		Explorative		High-impact		Technological diverse	
	Avg.	*Dummy*	*Avg.*	*Dummy*	*Avg.*	*Dummy*	*Avg.*	*Dummy*
	(Va)	(Vb)	(VIa)	(VIb)	(VIIa)	(VIIb)	(VIIIa)	(VIIIb)
FI × Treat	0.001	0.006	0.002	0.032***	0.010*	0.035**	-0.021*	-0.020
	(0.006)	(0.005)	(0.003)	(0.011)	(0.005)	(0.014)	(0.012)	(0.015)
Additional controls (in top and bottom panels):								
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

Notes: The table presents estimates from panel regressions explaining the effect of the FSAP on the full set of patent quality-related measures as introduced in Section 3.2 and defined in Table 2. The table displays the DID coefficients equivalent to Column III in Table 4, using respective measures as dependent variable. All columns denoted with *a* measure the respective dependent variables by the average value in each year. All columns denoted with *b* measure the respective dependent variables using each year's maximum value. 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.

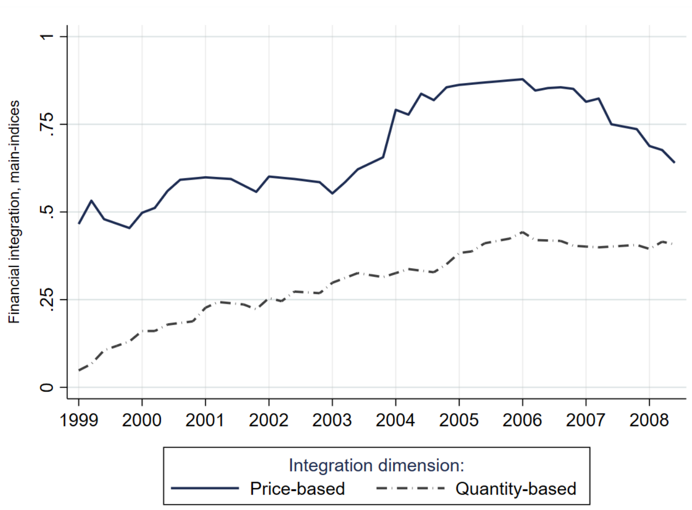
Table A5: Patent quality estimations using the placebo event

	Technological quality			
Dependent Variable:	Forward Citations		Claims	
Treatment measure:	Binary	Continuous	Binary	Continuous
	(I)	(II)	(III)	(IV)
$FI^{\text{placebo}} \times$ Treat	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)
$FI^{\text{placebo}} \times$ Treat	-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

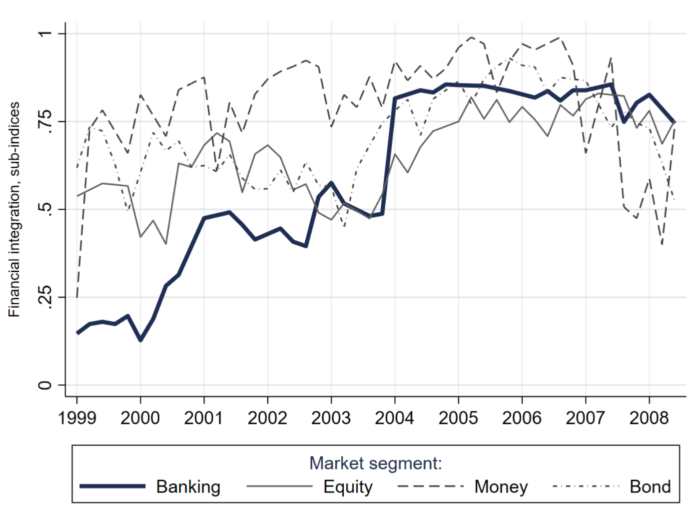
Notes: This table presents a set of robustness tests on the placebo setting. The placebo estimations are identical to Columns II and IV in Table 6, except that they use the patent quality and market value variables defined in Table 2 as dependent variables. All remaining variables are defined as in the 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: Aggregate statistics: *de facto* financial integration measures

Panel A: Main indices: Price- and Quantity-based financial integration measures



Panel B: Sub-indices: Banking sector integration and related subindices

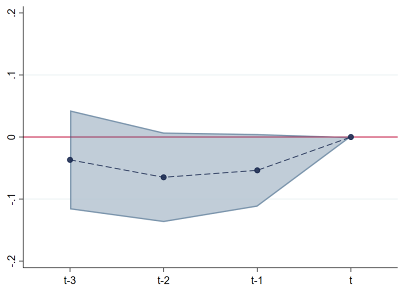


Notes: The figures plot *de facto* measures of financial integration as defined in Hoffmann *et al.* (2020) for the years from 1999 to 2008. Panel A displays two aggregate measures. The solid line refers to the ECB's quantity-based composite indicator measuring monetary financial institutions' (MFI) loans to non-financial corporations. The quantity-based indicators use data on the international portfolio composition of investment funds and banks (i.e., MFIs). The indicators are computed as intra-euro area cross-border holdings expressed as a share of euro area total holdings. The dashed 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. These aggregate price-based indicator averages the scores of four segments: money markets, bond markets, equity markets, and banking markets. In Panel B, the four price-based indicators are displayed separately. The banking market indicator is the bold solid line. The banking market indicator represents the loans and the liability (deposits) side of bank balance sheets and considers households and non-financial corporations as counterparties. The indicator computes cross-country dispersion measures for bank lending and deposit rates on the interest rates for both new loans on deposits with agreed maturity. See Hoffmann *et al.* (2020) for a detailed description of the different measures.

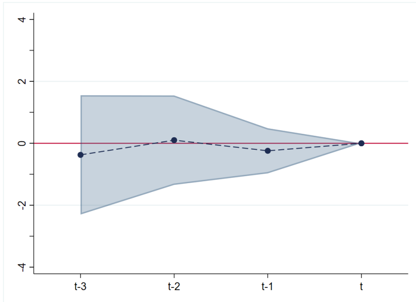
Figure A2: Pre-treatment DID regression coefficients: Testing for parallel trend

Panel A: Anticipatory effects on main outcome variables

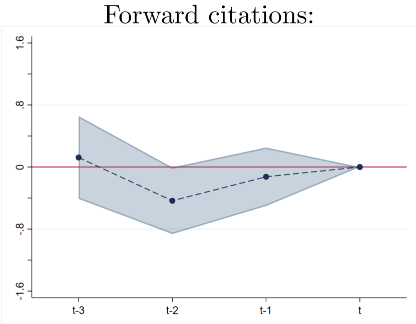
Bank loans:



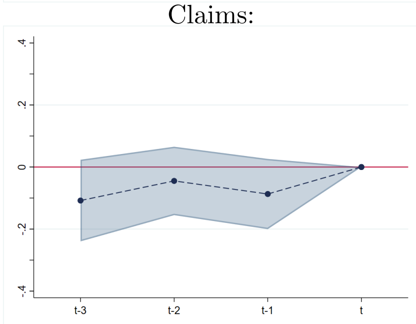
Patent filings:



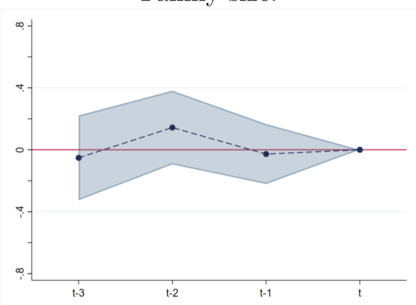
Forward citations:



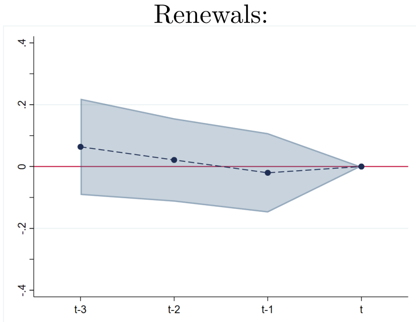
Claims:



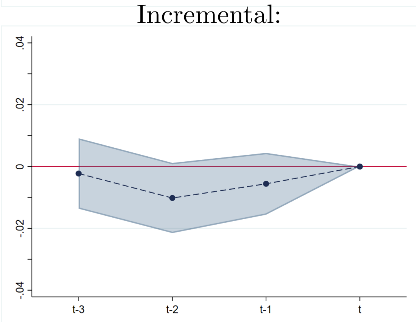
Family size:



Renewals:



Incremental:



Explorative:

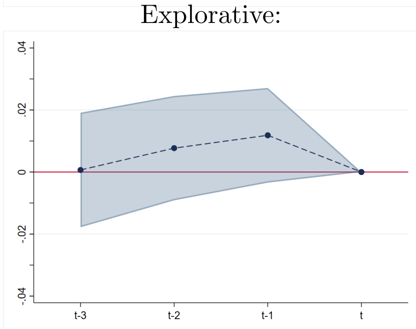


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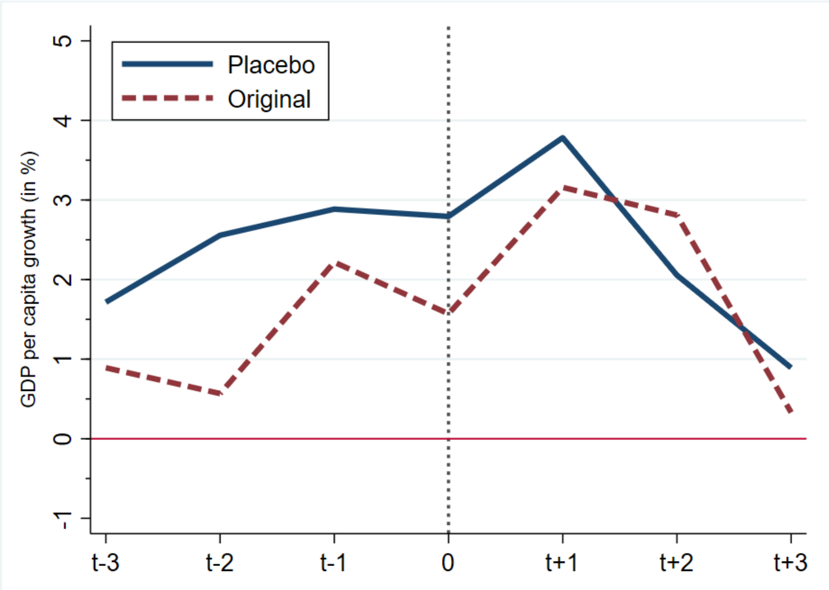
Figure A2 (*continued*)

Panel B: Pre-treatment trend regarding different patenting dimensions

Patenting dimensions:			Technological quality	
Dependent variables:	Bank debt (log.)	Patent filings	Forward citations	Claims
	(Ia)	(IIa)	(IIIa)	(IVa)
Exposure × 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
	(I)	(II)	(III)	(IV)
Exposure × 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

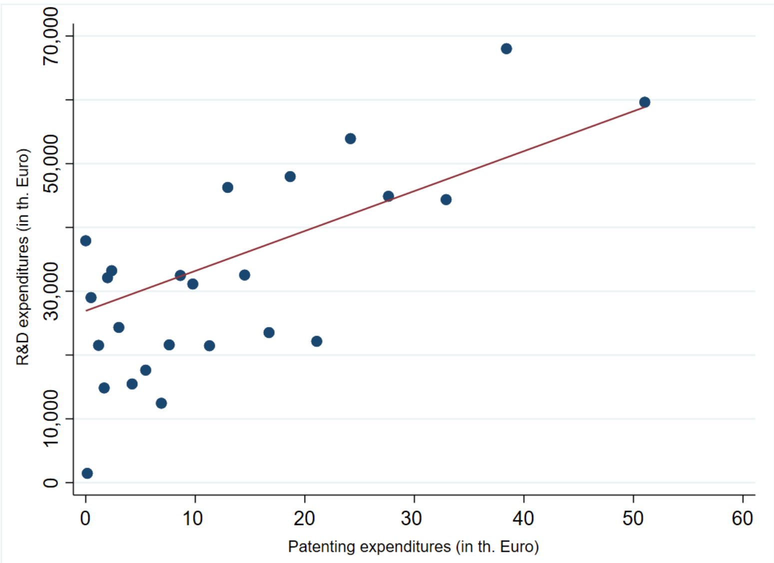
Notes: Panel A and B display tests on parallel trends between treated and control group firms during the pre-FSAP integration phase. Panel A plots coefficients of the interaction terms of year- and treatment dummy variables. Year dummies resemble the country-specific years before the treatment is initiated, 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 B 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 $treat$, indicating whether a firm belongs to the treatment group 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.

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.[19] 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

[19]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.