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Leveraging intellectual property: The value of harmonized enforcement regimes ☆

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ABSTRACT

This paper examines the role of intellectual property (IP) law as a determinant for external debt financing of innovative firms. For identification, we exploit exogenous variation in patent right enforcement arising from the 2004 EU Enforcement Directive. This major policy reform strengthened IP rights and, thus, raised patent owners' asset position. We find that patenting firms significantly increase their use of debt and benefit from lower interest rates in response to the amendment, especially if they own valuable patent portfolios. These effects are most pronounced for relatively small and financially constrained firms, emphasizing the importance of the legal framework in fostering debt financing activities of innovation-oriented firms.

1. Introduction

External debt financing activities are often accompanied by severe agency issues, leading to higher refinancing costs, lower levels of investment, and credit rationing. Innovation-intensive firms are particularly susceptible to these challenges due to their pronounced informational opacity and the high valuation risks of their assets (e.g., Hall and Lerner 2010). These firms can moderate such issues and, thus, improve their access to external debt financing by obtaining legal protection for their inventive output through formally granted intellectual property (IP) rights, such as patents (Mann 2018; Farre-Mensa et al. 2020; Horsch et al. 2021). However, relative to tangible assets, enforcing granted IP rights through the legal system remains complex (Lemley and Shapiro 2005; Cohen et al. 2019), suggesting that the extent to which firms can enforce their patents may affect how well they can exploit them for financing activities.

This study provides new evidence on the role of the legal framework for the financing activities of innovative firms. Specifically, we examine how the legal enforcement of patent rights affects debt financing of patenting firms. We posit that more rigorous enforcement regimes help firms to leverage patents for external debt financing as they strengthen the exclusive rights to exploit their inventions. To establish a causal link between patent enforcement law and debt financing, our empirical analysis uses the 2004 EU Enforcement Directive (2004/48/EC) as an identifying event. The directive was a major reform that significantly reduced uncertainty about patent enforcement across Europe (Petillion 2019).

Using a difference-in-differences (DID) design, we find that the Enforcement Directive significantly raised patenting firms' use of debt. Specifically, our baseline model uses variation across time arising from the staggered adoption of the directive across EU member states and distinguishes firms with relatively high and low ex-ante patenting ac-

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tivities as cross-sectional variation in the exposure to the treatment. Our results show that firms with more valuable patent portfolios before the legal amendments raised their long-term debt-to-asset ratios by a disproportional 20% (2.5 pp) compared to firms with relatively less valuable portfolios, controlling for common capital structure determinants as well as country-year and firm fixed effects. The increase in the use of long-term debt is most pronounced for relatively young, private, and small firms, which benefited from lower interest burdens the most. The treatment effects are also positive but more moderate when using firms' total debt ratio as the dependent variable. There is no effect on short-term debt, which is a more common debt financing mode for risky borrowers (see Lim et al. 2020). Hence, these results emphasize the mechanism behind the main findings: strong patent enforcement supports debt financing by reducing the risk associated with patents.

Our sample mainly combines financial information from the ORBIS database for 5,677 firms with in-depth European patent data from PAT-STAT on 96,800 individual patents and spans 12 years (2001-2012). We augment this data with granular information on patent fee schedules, hand-collected details on the reforms of the Enforcement Directive, and previously unexplored patent collateral data. This unique sample represents the European business landscape well, comprising predominantly private, small and medium-sized enterprises (SMEs) from ten different European countries and virtually all industries. This composition is advantageous for our analyses since credit availability may matter most for SMEs (e.g., Beck et al. 2005; Berger and Udell 2006; Carbo-Valverde et al. 2009), and improving access to finance is a common incentive for these firms to patent (Graham et al. 2009; EPO 2017).¹ Our measurement strategy to quantify firms' patent portfolios tracks compulsory payments of patent renewal fees on the firm level. As we show, this approach is helpful because, unlike most other indicators, patent expenditures consistently measure the size and value of actively held patent portfolios for each firm and year.

We extend the baseline analyses along multiple dimensions. First, we quantify the country-specific treatment intensity by collecting detailed information on the legislative changes of each country. The effects are strongest for firms domiciled in countries with more amendments to the existing domestic laws, and they increase with the number of new articles implemented. Second, we show that the effects of the Enforcement Directive are most pronounced for firms facing stronger ex-ante competition. This finding corroborates prior research showing that enhancing exclusive ownership rights (i.e., patent rights) is most relevant for firms in more competitive environments (Aghion et al. 2015). Third, we mitigate concerns that potentially confounding factors related to differences in observable firm characteristics bias our findings. To do so, we expand the main sample with non-patenting firms and match them to patenting firms using Coarsened Exact Matching (CEM). Estimates from this setting are similar to the main findings regarding significance and magnitude. Fourth, we demonstrate that timely proximate events to the treatment period (e.g., the Global Financial Crisis) are unlikely to account for the main results. We also show that undesirable biases potentially arising from the staggered treatment effects, as described in Baker et al. (2022), are unlikely to confound our results. Fifth, we find no disproportional response in equity financing for treated firms to the Enforcement Directive and in factors determining their loan demand. These results suggest that the baseline effects are driven by a shift in the supply of external debt financing.

To elicit potential mechanisms, we investigate responses to the change in law with respect to differences in firm characteristics. The positive estimates of the Enforcement Directive on firms' long-term debt ratios are most pronounced for innovation-intensive firms with limited access to external financing sources, such as private, relatively young,

and smaller firms. Similarly, firms with higher ex-ante financing constraints or dependence on external financing disproportionately increase long-term debt ratios after the legal amendment. Moreover, we find that those firms that raise more debt in response to the Enforcement Directive benefit from significantly lower costs of obtaining debt by about 10% in interest expenses. Again, this effect is most pronounced for young, private SMEs. These results underline that the Enforcement Directive shifts the supply of loans and emphasizes the importance of the legal framework to promote financing activities, especially for small, vulnerable firms.

Finally, we provide evidence that the Enforcement Directive helped firms leverage their patent portfolios for financing purposes by fostering cash flow-based lending in addition to asset-based lending. To examine this, we introduce previously undisclosed information on patent loan collateral from administrative sources. We first show that firms use patents as collateral to raise debt financing, consistent with previous studies (e.g., Mann 2018). Moreover, we find that the changes in long-term debt ratios can largely be explained by firms that do not pledge their patents. This finding echoes recent evidence showing that most loan agreements of non-financial firms are based on expected cash flows and not collateralized assets (Lian and Ma 2021; Ivashina et al. 2022; Kermani and Ma 2022). With relatively low liquidation recovery rates of intangible assets (Kermani and Ma 2023), the expected going-concern value of patenting firms should be most decisive for raising debt. Enhanced patent enforcement seems to benefit these firms by reducing uncertainty about the expected value of their patent portfolios.

This paper contributes to the existing literature in multiple ways. Most broadly, our findings add to the literature on financing activities of innovative firms (e.g., Hall and Lerner 2010; Kerr and Nanda 2015). In this context, we focus on the most common type of external financing, i.e., debt financing (e.g., Berger and Udell 2006; Carbo-Valverde et al. 2009). The importance of external debt financing for innovative firms is well-established. Firms can directly exploit IP assets, such as patents, to satisfy their financing needs via licensing, IP sales, or collateralization (Arora et al. 2001; Gambardella et al. 2007; Serrano 2010; Mann 2018; Horsch et al. 2021). More indirectly, patents benefit firms as they are legally approved signals that reduce information asymmetries, eventually enhancing debt financing and reducing firms' cost of debt (Cornaggia et al. 2015; Chava et al. 2017; Farre-Mensa et al. 2020; Saidi and Žaldokas 2021). By focussing on debt financing, we also account for the fact that our sample fairly represents the actual business landscape and, thus, consists mainly of bank-dependent firms.

Our findings provide new evidence on the legal environment as a determinant for firms to leverage their innovation for accessing debt financing. Previous studies have considered how changes in IP law affect firms' business activities (Gould and Gruben 1996; Kanwar and Evensov 2003; Qian 2007; Galasso and Schankerman 2010; Aghion et al. 2015; Mezzanotti 2021). There is reason to believe that IP law affects debt financing. Alimov (2019) finds that IP right reforms correlate with lower loan spreads and higher loan amounts on an aggregate level, especially in more innovation-intensive industries. Relatedly, Chava et al. (2017) study how US banks adjust their loan pricing for large patenting US corporations in response to the WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Unlike these studies, we directly analyze the role of IP law on debt financing using a hitherto unexplored empirical setting, the 2004 EU Enforcement Directive. The reform arguably marks the most significant change in IP law in Europe since TRIPS in 1995. We extend prior research that ascertains the stimulating effect of the Enforcement Directive for IP protection across Europe (e.g., Petillion 2019) by showing that the amendments stimulated patenting firms' debt financing. Hence, this study reveals a previously undisclosed benefit of the directive, especially for financially constrained, small, bank-dependent firms. Moreover, we assess the effects of IP reforms and their determinants for innovation-oriented borrowers using large-scale, micro-level financial data on mostly private SMEs from different countries. As a side result, our study also provides

¹ Consistent with these features of our sample, the baseline estimates also apply when measuring long-term debt financing in logs or year-over-year growth rates, but not for equity.

new insights into the heavily debated issue of the high fragmentation in the global patent system. This policy concern has prevailed despite international agreements such as TRIPS (see Harhoff et al. 2009; Hall and Helmers 2019; Veugelers and Harhoff 2023). In sum, the findings of this study enhance the understanding of the role of law in innovative firms' debt financing activities and emphasize the importance of an effective and harmonized legal IP framework to promote debt financing of innovation-oriented firms.

The remainder of the paper is organized as follows. Section 2 provides the institutional background. Section 3 introduces the patent portfolio measures, describes the data, and outlines the empirical strategy. Sections 4 and 5 present the main results, robustness tests, and mechanisms. Section 6 concludes.

2. Institutional background

In April 2004, the European Parliament and the Council announced Directive 2004/48/EC on the enforcement of intellectual property rights, the so-called Enforcement Directive. Until the early 2000s, a lack of IP right enforcement led to substantial damages in the EU, with firms losing an estimated 400-800 million Euros due to counterfeiting and piracy (European Commission 2000, 2003). The general objective of the Enforcement Directive was to ensure a high and homogeneous level of protection of IP rights across the EU. To achieve this, it set out several measures, procedures, and remedies to promote the legal enforcement applicable to the infringement of patents or any other IP rights.² The reform became effective at different points in time across EU member states throughout the subsequent five years and marked a major shift in the European IP enforcement regime.

The Enforcement Directive enhanced patent protection in Europe in mainly two ways. First, it strengthened the patent system as a whole by implementing measures to increase the reliability and effectiveness of patent enforcement. For example, the amendments expanded the remedies for right holders by introducing several provisional measures, asset-freezing injunctions, market recall, and an obligatory right of information (Petillion 2019). Second, the Enforcement Directive created a more level playing field across EU member states regarding the enforcement of IP rights. This harmonization effort was crucial in the European context since there was no unified patent court at the time (see Veugelers and Harhoff 2023). Unlike in other large jurisdictions, European patents are bundles of multiple national patents. This fragmentation in IP law complicated consistent enforcement across Europe and was particularly strong until the mid-2000s (Hall and Helmers 2019). In such an environment, the harmonization of laws across otherwise well-integrated member states resembled a strengthening of the legal framework by itself. Hence, the amendments of the Enforcement Directive were particularly important as they added new legislation and created a more level playing field across EU member states.

The general impact of the Enforcement Directive is well-documented. A comprehensive evaluation study of the EU (2017) ascertains that the Directive was an effective tool to harmonize the enforcement of IP rights across member states. It strengthened the legal boundaries of IP rights, preventing infringements by closing country-specific loopholes. As such, Fleissner (2009) finds that the amendments enhanced resilience against illegal copying. For example, the Enforcement Directive introduced the right of information (Article 8), which significantly facilitated the detection of IP right infringements by granting access to the origin and distribution networks of goods (Petillion 2019). The rule was implemented in all member states and rapidly gained traction: Five years after the Enforcement Directive's announcement, 12% of IP-related court cases in the EU applied this Article (EU 2017). As another

tangible outcome, the Enforcement Directive significantly reduced the duration of patent-related court cases (EU 2017). This observation is consistent with evidence on other harmonization efforts in IP enforcement, such as the unification of the US patent court system in 1982 (see Galasso and Schankerman 2010).

We expect the advances in patent enforcement stipulated by the Enforcement Directive to be vital for debt financing as they reduce uncertainty about patents' validity and scope. In general, clearly defining property rights is essential for the functioning of markets, especially concerning IP rights (Cohen et al. 2019). Patents provide their owners a competitive advantage by legally conferring exclusive ownership rights (e.g., Farre-Mensa et al. 2020). However, market imperfections mitigate this advantage, such as the uncertainty associated with the ability to enforce patents through the legal system. Legal uncertainty is a key characteristic of patents that remains even after the formal granting of patents by competent authorities (Lemley and Shapiro 2005; Gans et al. 2008). The fragmentation of IP law and poor enforcement of property rights likely elevates this issue. Importantly, uncertainty regarding the applicability of patent claims creates valuation issues of future expected cash flows associated with them.

In contrast, however, more thorough and harmonized patent enforcement mitigates uncertainty by definition, thereby sharpening the legal boundaries of patents (Galasso and Schankerman 2010). Hence, reducing legal uncertainty should mitigate valuation issues of future expected cash flows associated with patents. This feature is important for debt financing because cash flows associated with borrowers' assets are integral for lenders to provide debt (e.g., Lian and Ma 2021; Kermani and Ma 2023). From a lender's perspective, they indicate the ability to serve interest payments and, thus, directly impact the risk of default. Improved patent enforcement should facilitate the assessment of firms' cash flow position and potentially increase the expected value associated with the temporary monopoly right of a patent. Therefore, enhanced enforcement likely raises lenders' willingness to supply debt to patent owners. Against this background, we hypothesize that the use of debt by patenting firms increases in response to the Enforcement Directive.

These considerations resonate with a large body of research. Previous studies identify the strength of patent protection and the perseverance of patent enforcement as crucial determinants for inventors to appropriate returns on their IP (Branstetter et al. 2006; Bessen and Maskin 2009; Aghion et al. 2015). In line with this, enhanced patent protection deters free-riding on other firms' inventions and shortens legal disputes, which accelerates technological diffusion (Gambardella et al. 2007; Galasso and Schankerman 2010). These aspects have direct implications for firms' financing activities: For example, more effective patent protection enhances the propensity to license patents in the absence of complementary assets (Arora and Ceccagnoli 2006) and induces banks to adjust loan pricing (Chava et al. 2017). In a theoretical framework, Rampini and Viswanathan (2013) argue that limited enforcement of asset rights determines collateral constraints. Alimov (2019) finds empirical support for this reasoning, showing that IP right reforms are associated with increased aggregate debt capacities, particularly in IP-intensive sectors.

As a central identifying assumption, we consider the Enforcement Directive as an exogenous shift in the legal environment that is unrelated to firm-level (financing) activities. As such, the timing of the adoption of EU directives to domestic legislation is unlikely to pick up market responses because it is mainly attributed to differences in national legislative procedures (see Kalemli-Özcan et al. 2013; Christensen et al. 2016). In line with this, the implementation dates of the Enforcement Directive vary considerably across member states (see Table IA2 in the Internet Appendix A). For example, Denmark, Italy, and the United Kingdom passed the amendments through domestic legislation in April 2006, while Germany, France, and Sweden implemented them only two to three years later. While this aspect relates to differences in implementation dates, other conceptual considerations further mitigate

² Table IA1 (Internet Appendix A) summarizes the principal articles of the Enforcement Directive. Internet Appendix C provides supplementary details on the Enforcement Directive.

endogeneity concerns. For example, the implementation decisions on EU law are made on a supra-national level, while firm-level activities may rather trigger country-specific initiatives (Schnabel and Seckinger 2019). Individual firms' actions are unlikely to endogenously affect large-scale policies, especially in our empirical setting that primarily covers SMEs. Moreover, our estimation approach utilizes heterogeneity in patenting activities and firm characteristics *before* the Enforcement Directive's country-specific adoption (see Section 3.3). We thereby directly address endogeneity concerns because the complexity of legal procedures and the associated time lags make it unlikely that firms adjust their innovative processes in anticipation of (uncertain) future policy changes. Finally, the Enforcement Directive targeted creating an environment more conducive to innovation (see Article 1), while the key outcome of interest in the empirical analyses is firms' financing activities. As such, it would be implausible for the EU to significantly adjust its legal framework regarding the enforceability of patents to steer firm-level financing activities.

3. Measurement, data sources, and empirical strategy

3.1. Measuring firm-level patent portfolios

3.1.1. Institutional background: patent fee requirements in Europe

IP law stipulates that patent holders must pay administrative fees to activate and sustain the protection of their inventions. In Europe, renewal fees have to be paid for every year, usually beginning with the third year after the initial application, and according to the geographical scope of the patent. The geographical scope refers to the number of member countries of the European Patent Convention (EPC)³ in which patents protection is sought.

As a result, a distinct feature of the European patent system is that patent protection can be obtained and sustained independently across national patent offices. Patent holders have to choose whether to maintain protection every year and on a country-by-country basis, leading patenting costs to vary substantially with the number of designated countries (see Panel A of Fig. 1). This feature differs from those in other leading jurisdictions worldwide. For example, a patent granted by the US patent office (USPTO) requires only three renewals over 20 years and grants protection in all US states simultaneously.

Furthermore, renewal fees vary across patent life. They are relatively low during the first years after patent filing but increase over time, making the last years of a patent's life the most expensive. This structure applies to all EPC jurisdictions, but the exact amount of fees differs across member countries. Consequently, renewal fees can reach substantial amounts, especially if owners hold their patents in multiple jurisdictions over a long time. Indeed, patent fees in Europe are among the highest compared with other patent-intensive economies (de la Potterie 2010). Depending on the geographical scope, patent maintenance in Europe is five to twenty times higher than in the US. Panel B of Fig. 1 displays the average patent portfolio costs and the fraction of the renewal fees among total costs in Europe.

3.1.2. Measurement approach

Our measurement approach leverages the fact that renewal payments provide a precise picture of patent ownership and consistently measure patent values. We incorporate these aspects in two patent portfolio measures. First, we track annual renewal payments for each patent to identify firms' actively held patents at any given point in time after filing. Information on the actual patent status is crucial because

³ As of March 2022, Contracting States are Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, the Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

only about 50% of patent applications are eventually granted in Europe (Harhoff 2016), with another 50% of the granted patents not being renewed within the first eight years after application. The renewal fee payments *de facto* prove patent ownership at each given year. Moreover, we also use the annual renewal information to determine the exact geographical scope of a patent, as they flag each country where protection applies. This component is essential for integrating the patent value dimension: Previous literature identifies a strong positive relationship between the value of a patent, its geographical coverage, and maintenance over time (Harhoff et al. 2003; Hall et al. 2005; Bessen 2008). We combine the information on ownership and geographical coverage to calculate the first patenting measure, which equals the product of the number of actively held patents times the number of jurisdictions in which patents are active on a firm-year level. We refer to this portfolio size measure as firms' actively held *patent stock*.

Second, we augment this measure with information on firms' patenting expenditures. Specifically, we manually collect the actual amount of the obligatory patent fees using administrative documentation of the fee schedules from the European Patent Office. Table IA2 (Internet Appendix A) summarizes the fee schedule in a patent year-country matrix. We use information on the designated jurisdictions and the age of individual patents to calculate annual firm-level patenting expenditures. For consistency, the cost measure comprises all standard fees that arise during the first years after submission of the patent application, including expenses related to the patent application and grant.⁴ We add all cost items for each firm-year observation and refer to this measure as a firm's *patent costs*. Summarized, we define the two main patent measures as:

$$patent\ stock_{it} = \sum_{p=1}^n act.\ patents_{pit} \times jurisdictions_{pit} \quad \text{and} \quad (1)$$

$$patent\ costs_{it} = \sum_{p=1}^n fees_{it} \quad , \quad (2)$$

where $jurisdictions_{pit}$ is the number of jurisdictions at which all individual patents p held by firm i at time t are designated and active ($act.\ patents_{pit}$). Annual patenting costs of firm i resemble the total expenditures to maintain a patent portfolio, which is the sum of all fees required to maintain protection of all individual patents p (1... n) in year t in all designated jurisdictions. We normalize patenting variables on an industry-year basis to mitigate concerns regarding strategic patenting behavior correlated with the industry- and time-specific characteristics of firms (see Lerner and Seru 2022).⁵ To ensure that the distinct variable definitions do not drive results, we test different definitions in our main analysis.

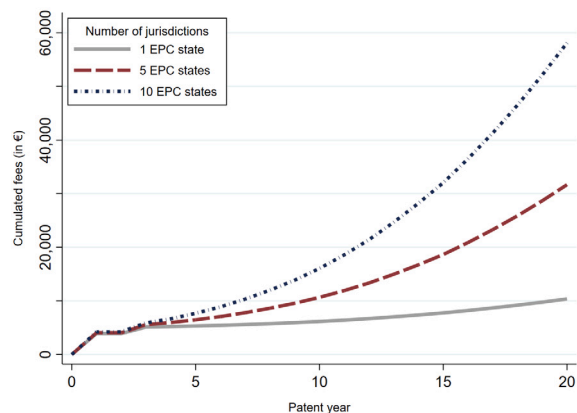
3.1.3. Descriptive statistics and the relation of patenting expenditures and portfolio values

Table 1 displays summary statistics on different patent measures. The average annual cost per patent is 1,500 Euros, and the average portfolio cost is 26,700 Euros. These relatively low values reflect that a large share of patents is not influential for subsequent innovation; most patents have little value, while some patents reach significant economic amounts. Patent portfolios in the top five (one) percentile of the cost distribution accrue costs of approximately 8.3 million Euros (49.4 million

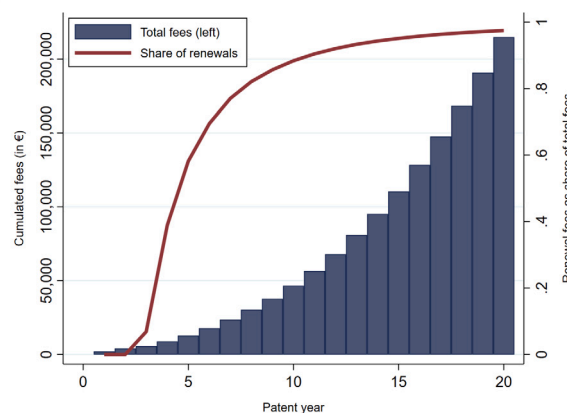
⁴ Application costs include fees for the examination, international search, translation, and filing of patents. Once granted, firms have to pay designation and grant fees. We sum up all application- and grant-related costs and assign them evenly to the first three years of patent life, during which most jurisdictions do not charge renewal fees. We do not consider fees related to patent litigation, as most patents never confront judicial trials (e.g., Gans et al. 2008). Table IA3 (Internet Appendix A) contains an example calculation of annual fees.

⁵ Normalized values, \bar{p}_i , of any patent variable, p , for firm i in period t are calculated by: $\bar{p}_{it} = p_{it} / Q99\ p_{st}$. Accounting for outliers, $Q99\ p_{st}$ is the 99th percentile value of variable p in sector s at time t and replaces all $p_{it} > Q99\ p_{st}$.

Panel A: Patent costs and geographical scope



Panel B: Patent portfolio costs and renewal fees



Notes: The two graphs illustrate the patent fee structures over the patent life cycle and regarding obligatory administrative fees for patents active in EPC member states. Panel A displays the accumulated amount of annual fees necessary to maintain the protection of one patent for each of the maximum 20 years of patent life. These costs include the most common application, grant, and renewal fees and are subject to change over time. For illustration purposes, we select the 2006 reference payment schedule, see Table IA1 (Internet Appendix A). Costs refer to the average fees, which actually vary on a country-by-country level. The graph plots these fees distinguishing the numbers of designated jurisdictions in which the patent is renewed: 1, 5, or 10 jurisdictions, respectively. The blue bars in Panel B exemplify the cumulative amount of all patent portfolio fees over the patent life span of an average portfolio (indexed on the left axis). The red line in Panel B displays the share of renewal costs among total patenting costs for this average portfolio. To illustrate, the *average* firm in the sample holds five patents across eight jurisdictions, see Table IA3 (Internet Appendix A).

Fig. 1. Patent costs over the patent life cycle (in Europe). (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

Table 1
Descriptive statistics on patenting measures.

	Patent costs (portfolio)	Avg. patent costs (per patent)	Patent stock	Citations (portfolio)	Avg. citations (per patent)	Generality index
Mean	24,690.2	1,506	72.30	24.48	3.23	0.15
Std. dev.	157,243	987.6	357.8	132.20	3.70	0.18
Min.	25.67	4	1	0	0	0
Max.	9,715,573	4,729	12,930	6,048	20	0.83
Percentiles						
p1	111.42	70	1	0	0	0
p5	398.74	198.36	1	0	0	0
p10	808.11	338.33	2	0	0	0
p25	2,115.38	713.31	4	1	1	0
p50	5,280.00	1,400.93	19	5	2	0.07
p75	13,209.1	2,081.44	41	14	4.33	0.25
p90	35,810.8	2,625.53	115	39	7.50	0.44
p95	71,221.2	3,350.48	223	74	10.13	0.50
p99	322,024	4,729.07	950	343	20	0.66

Notes: This table provides summary statistics comparing cost-related patent measures introduced in Section 3 with two commonly used patent measures (citations and generality). Column I contains the total costs of firms' patent portfolios as defined in Equation (2). Column II displays the average costs per patent within firms' portfolios. Column III displays portfolio values measured by patent stock as defined in Equation (1). Columns IV and V contain the total and the average number of citations of all patents in a given firm's patent portfolio, considering citations received within the first eight years after patent application. Column VI contains the average value of respective patents' generality measure, which we compute following Hall et al. (2005).

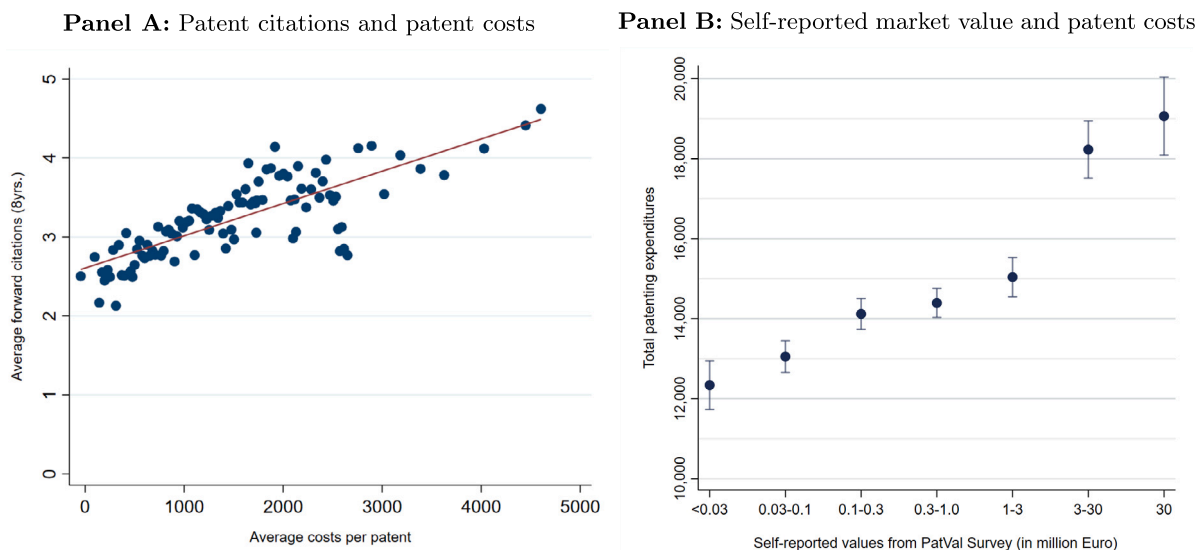
Euros) over their lifespan, given the average patent life in our sample of eleven years. These observations echo prior studies documenting highly skewed distributions of patent values (e.g., Gambardella et al. 2007).

Table 1 includes the corresponding values of two commonly used proxies for the technological quality of patents. First, patent citation counts approximate a patented invention's technological importance and economic value (e.g., de Rassenfosse and Jaffe 2018). Second, patent generality measures the technological breadth associated with patents. Broader patents indicate relevance across more technology classes and thus indicate particularly valuable technologies (see Hall et al. 2005). We find that the distributions of these quality measures are

highly skewed, just like the patent cost variables (see Columns IV-VI).⁶ Yet, variation in the citation-based variables is relatively low compared to the patent expenditure-related measures, especially in the lower tail of the distribution.

Furthermore, for the validity of our measurement approach, it is essential to show that high patent costs can be associated with high-value patent portfolios. Indeed, the market value of patents is likely

⁶ The statistics are in line with previous observations. Most patents receive little or no citations and have low generality scores. For example, about 19% of patents in our sample receive no citation compared to 16% in Kogan et al. (2017).



Notes: In Panel A, the binned scatter plot relates the average number of forward citations received by a patent within the first eight years after filing to the average costs per patent. The graph compares within portfolio averages and accounts for mechanical effects arising from age differences by controlling for the average portfolio age and the age of the firm. The number of bins is 100. The red line is the linear fit. Panel B plots the average patenting expenditures arising over the entire lifespan of any given patent to the self-reported value by its inventor. Data is obtained from the PatVal-EU survey (Giuri et al. 2007). Whiskers present the 95 percent confidence intervals.

Fig. 2. Relating patent value measures to patenting costs.

to exceed the face value of maintenance costs, especially for valuable patents (see Bessen 2008). First, we relate patent costs to the two previously introduced patent indicators: patent citations and generality, which are associated with patent value but do not have a maximum threshold. Panel A of Fig. 2 maps average, firm-level patent costs to the average number of citations received within eight years after filing, a common adaptation in the literature (e.g., Lerner and Seru 2022). We find that higher patenting costs correspond to more citations. Moreover, the graph suggests that this relationship applies along the entire distribution of patenting expenses. Consistently, Figure IA1 (Internet Appendix B) shows that this observation also applies when using alternative patent cost measures, i.e., the logarithm of patent costs and the patent cost-to-asset ratio, but not for more simple patenting measures, such as the patent stock size and patent filings.

Second, we analyze the relationship between patenting costs and truly novel patents by determining the top 25, 10, and 1 percentile of the generality values and relating them to the calculated patent costs. We estimate this relationship, controlling for observable firm characteristics, country-year and firm fixed effects (the model specification is below the table). Using maximum values identifies breakthrough patents better than considering portfolio averages, and it accounts for the fact that firms may have only relatively small patent portfolios. Results in Table 2 show a robust positive association between patenting expenditures and truly novel patents. Estimates are statistically significant at the one percent level and hold across different specifications. In line with our measurement strategy, the size of the point estimates increases for higher values of the generality score.

In a third test, we relate the total costs of individual patents to a direct measure of their monetary value, using self-reported patent values from the PatVal-EU survey (see Giuri et al. 2007). PatVal is a large-scale survey comprising detailed information from inventors on about 32,000 patents. The survey is representative of patents filed in France, Germany, Italy, the Netherlands, Spain, and the United Kingdom, i.e., countries in which more than 80% of sample firms are located. Amongst others, the survey asks inventors to “to estimate the minimum price at which the owner of the patent [...] would have sold the patent rights on the day on which the patent was granted” (Giuri et al. 2007, p. 15). For 7,659

patents in our sample, we can retrieve these patent values, which are measured in distinct ranges (minimum-maximum prices).⁷

Panel B of Fig. 2 shows a strong positive relationship between the self-reported PatVal patent price ranges and patenting expenses. For example, expenditures are, on average, 38% higher for self-reported values of at least 10 million Euros, compared to expenditure on patents corresponding to self-reported values of a maximum of one million Euros (18,967 versus 13,744 Euros, t-value: 17.94). Notably, the most valuable patents, as defined by our measure, also correspond to the most valuable patents in the PatVal survey. Figure IA2 (Internet Appendix B) displays additional statistics and shows that this relationship applies to different levels of aggregation. Hence, this section demonstrated multiple advantages of the cost-related measures as defined in Equations (1) and (2): They indicate ownership for every year and country, vary over time, feature a higher variation on the lower end of the distribution, and are informative about high-value patents, at least in relative terms.

3.2. Data and descriptive statistics

The main sample contains firm-level financial information from the ORBIS database provided by Bureau van Dijk covering 2000 until 2012 and ten European countries (Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Sweden, and the United Kingdom).⁸ Patent information stems from the PATSTAT database (Autumn 2019 vintage), which contains the full population of patent applications in our sample period. We match the two data sources and keep all firms

⁷ An benefit of the PatVal-values over other market values (e.g., Kogan et al. 2017) is that they cover small private firms.

⁸ We initially considered all 15 EU member states of the early 2000s, i.e., when the European Commission passed the Enforcement Directive. Due to insufficient coverage in the financial data, especially in the early 2000s, we exclude Austria, Greece, Portugal, and Spain. Further, we exclude Luxembourg because of its economy’s strong focus on the financial sector, which is not considered in the empirical analyses. Panel A of Table IA4 displays the country distribution of sample firms.

Table 2
Patenting costs and their relation to high impact patents.

Dependent variable:	Generality index					
	Top 25 percent		Top 10 percent		Top 1 percent	
	(I)	(II)	(III)	(IV)	(V)	(VI)
Patent portfolio costs	0.306*** (0.013)	0.289*** (0.014)	0.463*** (0.014)	0.441*** (0.015)	0.492*** (0.014)	0.471*** (0.014)
Additional controls:						
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	No	Yes	No	Yes
Country-Year FE	No	Yes	No	Yes	No	Yes
R ²	0.12	0.14	0.21	0.24	0.23	0.26
Observations	34,210	34,210	34,210	34,210	34,210	34,210

The table displays the coefficient γ_1 estimated on the following regression:

$$generality_{it}^q = \gamma + \gamma_1 patent\ costs_{it} + \gamma_2 X_{it} + u_{it} \quad \forall q \in \{25, 10, 1\}$$

Notes: The table presents regression estimates explaining the relationship between patent costs and the occurrence of high impact patents. The dependent variable is the top 25 (Columns I and II), 10 (Columns III and IV), and 1 percent (Columns V and VI) in the firm-year specific generality distribution. Patent generality is computed as suggested by Hall et al. (2005). In the regression specification below the table, X is a vector of controls for i) observable time-variant firm characteristics related to capital structure decisions by including a firm level controls (i.e., firm size, profitability, the share of tangible assets, and cash flow), ii) observable time-invariant firm characteristics by including firm fixed effects, iii) firm-year fixed effects that account for macroeconomic changes, and iv) country-industry fixed effects that account for industry-specific patenting behavior and institutional cost differences. Columns I, III, and V only differ in their use of fixed-effects, as indicated at the bottom of the table. Columns II, IV, and VI display the coefficient γ_1 from the equation above. For further variable descriptions, see Table IA5 (Internet Appendix A). Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

with at least one active EPO patent throughout the sampled period, excluding firms active in the financial or public sectors. The sample combines information on 96,800 individual patents with financial data of 5,677 firms aggregated in an unbalanced panel. For the firm-level regression analyses, we exclude all firms with zero or negative total assets and firms with missing values for all variables used in the main specification specified in Section 3.3 or missing industry class information. We allow firms to enter and leave the database to avoid survivorship bias. Further, we exclude singletons to eliminate upward biases regarding statistical significance, a common issue in linear regressions where fixed effects are nested within clusters (see Correia 2015). We winsorize all financial variables at the 1st and 99th percentile. These procedures yield a sample of 28,521 firm-year observations (3,898 firms). For an overview of the sampling process, see Panel B of Table IA4 (Internet Appendix A).

Table 3 (Panel A) displays definitions and summary statistics on financial and patenting variables.⁹ Overall, the main sample of patenting firms represents the European business landscape well, as most firms are privately held (92.4%). Firms are well-established and relatively small, with a median age of 20 years and a median number of employees of about 56. However, these numbers vary significantly as the sample includes many very young and small firms but also some relatively old and large corporations. Likewise, the average patenting activities vary strongly across and within firms, confirming the properties of patenting variables as outlined in Section 3.1. Generally, the manufacturing sector has the highest share of patenting firms and consistently comprises most sample firms, but all other major industries are still represented (see Panel C Table IA4 Internet Appendix A). Sample firms have an average long-term debt-to-assets ratio of about 14.8 percent. The average firm is profitable (8.7% return on assets) and has a positive cash flow ratio (7.2%).

Panel B of Table 3 compares observable characteristics of firms with relatively high and low patenting intensities before the initial adoption

of the Enforcement Directive. High and low patenting-intensive firms are defined as having an above or below-median ex-ante patent portfolio value. Firms with more valuable patent portfolios are relatively larger (in terms of total assets and employee counts) and have lower debt ratios. Consistent with the measurement approach, their patenting activities are significantly higher than those of firms with relatively less valuable patent portfolios. Yet, the two groups are similar regarding several other characteristics, such as profitability, asset tangibility, and cash flows.

3.3. Identification strategy and econometric model

General setting: The identification strategy exploits the implementation of the Enforcement Directive as a quasi-natural experiment enhancing patent enforcement across EU member states. As a starting point, we measure the relationship between the directive and patenting firms' debt ratios, controlling for the patent portfolio values and common capital structure determinants. Formally, we estimate:

$$Long\text{-}term\ debt\ ratio_{ict} = \alpha_1 Post_{ct} + \alpha_2 PVal_{it-1} + \alpha CS_{it} + \epsilon_{ict}, \quad (3)$$

where the dependent variable (*Long-term debt ratio*) is the firms' long-term debt-to-asset ratio measured by dividing total external debt outstanding at the end of the year with a maturity of at least one year over total assets. $Post_{ct}$ is the treatment variable that measures the adoption of the Enforcement Directive. It is a dummy equal to one for all years after its transposition into national legislation of the home country c of a firm, or zero otherwise.¹⁰ Hence, the coefficient α_1 captures the average change in long-term debt ratios of patenting firms, comparing pre- and post-treatment periods. Equation (3) – and all other specifications in the empirical analyses – further controls for differences in patent portfolio values as defined in Equations (1) and (2) of firm i at the beginning of

⁹ For more detailed definitions, Table IA5 in the Internet Appendix A summarizes all variables used in this study.

¹⁰ This approach implies that firms file patents in their home country. While this assumption is plausible, especially for SMEs, Section 4.3.2 shows that the main results are robust to using alternative definitions of this measure.

Table 3
Summary statistics and variable definitions.

Panel A: Descriptive statistics on key variables							
Variable	Definition (Orbis code)	Obs.	Mean	SD	Min.	Q50	Max.
Long-term debt ratio	Long-term debt-to-asset ratio; (ltdb/toas), in %.	28,521	14.821	21.113	0	6.040	100
Short-term debt ratio	Short-term debt (loan+cred) over total assets (toas), in %.	27,635	23.183	18.418	0	17.758	89.715
Debt ratio (total)	Total debt (loan+cred+ ltdb) over total assets (toas), in %.	28,521	36.994	24.817	0.047	32.920	121.020
Firm size	Logarithm of total assets (toas)	28,521	9.893	2.674	0	9.559	19.683
Profitability	Return on assets; ebit/toas	28,521	0.087	0.205	-1.204	0.104	0.568
Tangibility	Fixed-tangible assets (tfas) over total assets (toas)	28,521	0.223	0.195	0	0.171	1
Cash flow	Net cash flow (cf) over total assets (toas)	28,521	0.072	0.164	-0.944	0.089	0.488
Employees	Number of employees (empl)	24,099	1,584	6,928	1	56	51,939
Age	Time in full years since incorporation (date_of_incorp)	27,480	28.513	23.765	1	20	84
Quoted	Indicator for publicly listed firms (list)	28,521	0.076	0.264	0	0	1
Patents filed	Total patent applications p.a.	28,521	0.510	3.726	0	0	144
Active patents	Number of active patents in portfolio at the end of the year	28,521	5.090	29.586	0	1	1,335
Active jurisdictions	Average number of jurisdictions at which firms' patents are active	28,521	7.944	9.545	0	3.666	36

Panel B: Comparing pre-treatment characteristics of high and low patenting-intensive firms

Variable	Ex-ante patenting intensity				Differences in means
	High		Low		
	Mean	Q50	Mean	Q50	
Long-term debt ratio	12.291	3.193	14.695	4.510	-2.403
Short-term debt ratio	22.115	17.758	24.200	19.246	-2.085
Debt ratio (total)	33.597	28.917	37.844	34.160	-4.247
Firm size	10.271	9.952	9.391	9.232	0.880
Profitability	0.087	0.103	0.090	0.106	-0.003
Tangibility	0.216	0.171	0.227	0.171	-0.011
Cash flow	0.071	0.091	0.072	0.088	0.001
Employees	3,116	174.5	1,545	93	1,571
Age	30.766	21	26.402	18	4.364
Quoted	0.094	0	0.059	0	0.035
Patents filed	1.454	0	0.125	0	1.329
Active patents	11.049	3	1.067	1	9.981
Active jurisdictions	13.412	13.6	3.986	1	9.426

Notes: Panel A provides summary statistics on financial and patenting variables of sample firms. Financial variables include the main dependent variable, i.e., 'long-term debt ratio', the control variables that are indicated in all regressions as 'firm-level controls' (firm size, profitability, tangibility, and cash flow ratio), and general information on the firm. Additionally, patent information comprises patent filings per year, the absolute number of active patents held in a given year, and the average number of designated jurisdictions within a portfolio. All variables are defined in Table IA5 (Internet Appendix A). Panel B displays the mean and median values of these measures for patenting firms with high and low ex-ante patenting intensities. Here, the sample is the pre-treatment period, i.e., all years before to the country-specific adoption year of the Enforcement Directive.

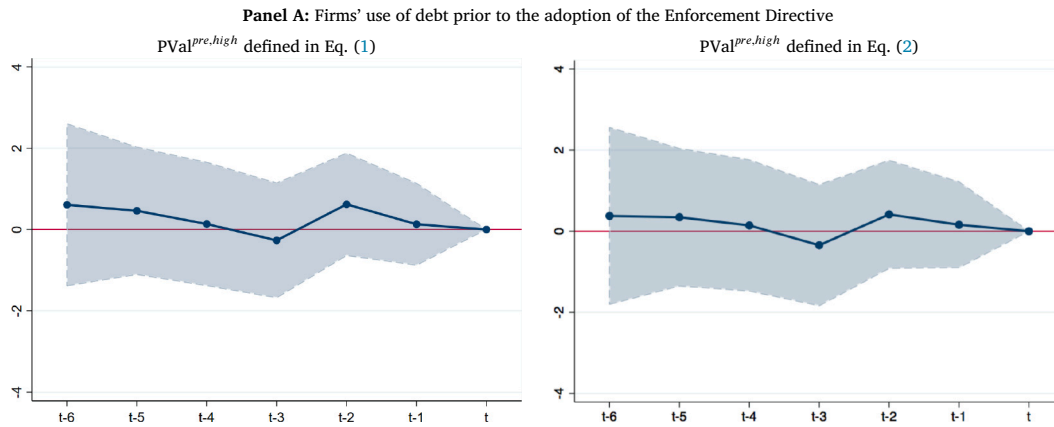
the period ($PVal_{it-1}$) and for time-variant firm-specific factors. Specifically, it includes a vector of the capital structure determinants (CS_{it}) of firm i in period t . CS_{it} that comprises the well-established capital structure determinants, i.e., firm size, profitability, share of tangible assets, and cash flow (see Graham and Leary 2011).

DID strategy: The Enforcement Directive does not explicitly target any subgroup such that, in principle, all firms are subject to the change in law. To identify the effect of patent enforcement on debt financing, we introduce additional cross-sectional variation in the patent portfolio characteristics of firms. More patenting-intensive firms should disproportionately respond to the Enforcement Directive because sharpening the legal boundaries of patent rights should be most relevant for firms with a high potential to leverage their patent portfolios. Enhanced en-

forcement should unleash this potential, which is likely more limited for firms with less valuable patent portfolios. To distinguish the response to the change in law, we classify firms with an above-median portfolio measure during the pre-treatment period (i.e., the average of all years in which $Post_{ct} = 0$) as more strongly affected. We deploy both portfolio measures as defined in Equations (1) and (2) for this classification throughout our analyses. Using categories (high versus low) is beneficial, as it mitigates concerns about the precision of the patent values at the tails of the distribution. We estimate the effect of patent enforcement on debt financing using a difference-in-differences (DID) methodology:

$$Long-term\ debt\ ratio_{ict} = \beta_1(PVal_i^{pre,high} \times Post_{ct}) + \beta_2 PVal_{it-1} + \beta CS_{it} + \varphi_i + \delta_{ct} + \varepsilon_{ict}. \quad (4)$$

Table 4
Testing for parallel trends.



Panel A plots the coefficients β_τ ($\forall \tau \in [-6, 0]$) estimated in the following regression:
 $Long\text{-}term\ debt\ ratio = \sum_{\tau=-6}^0 \beta_\tau PVal_i^{pre,high} + \beta CS_{it} + \varphi_i + \delta_{ct} + \varepsilon_{it}$

Panel B: Testing for pre-treatment trends					
Dependent variables:	Long-term debt ratio				
	(I)	(II)	(III)	(IV)	(V)
Time trend	-0.447*** (0.097)	-0.398*** (0.119)	-0.412*** (0.117)	-0.397*** (0.110)	-0.410*** (0.107)
Time trend $\times PVal_i^{pre,high}$		-0.158 (0.182)	-0.135 (0.181)		
Time trend \times Portfolio size ^{pre, high}				-0.244 (0.194)	
Time trend \times Patent filings ^{pre, high}					-0.239 (0.235)
<i>PVal</i> definition:	-	Eq. (1)	Eq. (2)	-	-
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.04	0.04	0.04	0.04	0.04
Observations	14,270	14,270	14,270	14,270	14,270

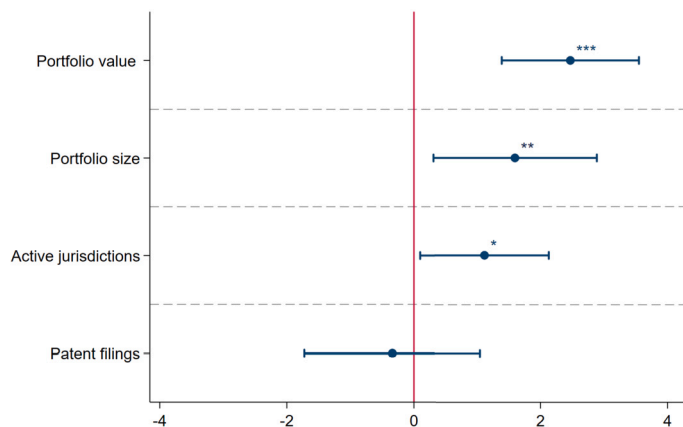
Notes: Panel A plots coefficients from estimations explaining changes in firms' long-term debt ratios during the pre-treatment period as defined below the figures. Variables are defined as specified in Equation (4). For estimating this, we restrict the sample to all country-specific years for which $Post = 0$. Unlike in the main specification, we include a set of interactions of year dummies with the $PVal_i^{pre,high}$ indicator, where year dummies indicate the relative number of country-specific years before the implementation of the Enforcement Directive. The implementation year, t , is the base year and both portfolio values are deployed separately. The shaded area marks the 95 percent confidence intervals of the estimates. Panel B presents estimates from regressions that explain firms' long-term debt ratios and test for deviating pre-trends among firms with high and low ex-ante patent portfolio values. Following Angrist and Pischke (2008), the sample comprises observations from the pre-treatment periods. The specification in Column I includes a time trend variable, i.e., a running number for each year) and adds the common firm-level controls and firm fixed-effects, which are both defined equivalently as in the baseline specification. In the remaining specifications, the trend variable measure is interacted with a dummy variable indicating if the firm has an above median portfolio value as defined according to the patent stock measure (Column II), the patent cost measure (Column III), the portfolio size (Column IV), and patent filings (Column V). Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

It is similar to Equation (3) but adds the interaction term ($PVal_i^{pre,high} \times Post_{ct}$), which is the product of the treatment variable, $Post_{ct}$, times a dummy variable, $PVal_i^{pre,high}$, that is equal to one for firms with above median ex-ante portfolio values, and zero otherwise. Hence, the coefficient of interest, β_1 , estimates the additional effect of the Enforcement Directive on the long-term debt ratios of firms with higher ex-ante patenting activities, i.e., the average treatment effect on the treated. Throughout the analysis, we refer to β_1 as the 'DID estimator'. Equation (4) controls for firm-specific time-invariant factors, such as business field-specific demand patterns for debt, by including firm fixed effects. Further, δ_{ct} are country-year fixed effects that account for general time-specific macroeconomic trends, such as general shifts in loan demand and supply.¹¹

Testing parallel pre-trends: Next, we show that firms with relatively high and low ex-ante patent portfolio measures have similar trends in debt ratios before the Enforcement Directive. Specifically, we estimate movements in debt financing using specifications similar to Equation (4) but for the pre-treatment period only. First, we add country-specific time dummies for each year preceding the initiation of the Enforcement Directive and their interactions with the $PVal_i^{pre,high}$ indicator. Panel A of Table 4 plots the estimates of these interactions and their corresponding 95 percent confidence intervals. The statistically insignificant coefficients for both patent measures indicate that the debt financing patterns of firms with high and low patent portfolio measures evolve in parallel trends throughout the pre-treatment period. For robustness, we

are relatively few countries in the sample, we test alternative specifications that cluster standard errors by country (undisplayed). Country-level clustering even increases the precision of our baseline estimates.

¹¹ Standard errors are clustered at the firm level in all regressions. To acknowledge that the variation across time occurs at the country level and that there



Notes: This figure plots the DID estimators (i.e., β_1 in Equation (4)) obtained from estimating the baseline specification. Estimations are repeated using different patent measures to determine firms' affectedness to the implementation of the Enforcement Directive. As the benchmark case, the first row displays the baseline specification that uses firms patent portfolio value as defined by Equations (1). The second and third row use the single components of the patent value variable: Firms are classified as treated with an ex-ante above median patent portfolio size (row 2), number of active jurisdictions (row 3), patent filings (row 4) in the period preceding the adoption of the Directive. Whiskers span the 90 percent confidence intervals. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Fig. 3. Patent portfolio values and leverage: pre- and post treatment comparison.

follow Angrist and Pischke (2008) and investigate pre-trends in an alternative way (see Panel B of Table 4). These specifications add a time trend variable and its interaction with the patenting variables to Equation (4). Estimates on these interactions are insignificant across several patenting variables. In sum, these results suggest that the classification approach of delineating more or less affected patenting firms does not violate the parallel trends assumption, which is crucial in our setting since firms with high- and low portfolio values differ along some observable features (see Section 3.2).

4. Empirical results

4.1. The Enforcement Directive and debt financing

We start by analyzing the relationship between the Enforcement Directive and patenting firms' use of debt. Column I of Table 5 displays results from estimating Equation (3). The coefficient for *Post* (0.862) suggests a statistically and economically significant increase of, on average, 6% comparing firms' pre- and post-implementation long-term debt ratios (with a mean dependent variable of 14.821, as displayed in Table 3). Column II shows that firms with valuable pre-treatment patent portfolios predominantly drive this relation. To do so, we add both firm fixed effects and the interaction $Post \times PVal^{pre,high}$ to Equation (3). The coefficient of this interaction term is positive, large, and significant at the one percent level, while the coefficient on the treatment variable turns insignificant.

Importantly, we next identify the effect of the Enforcement Directive on the debt ratios of firms with ex-ante higher patent portfolio values. Columns III and IV display estimations of the baseline specification defined in Equation (4) for both definitions of patent portfolios. In both specifications, the coefficients of the DID estimators are positive, highly significant, and sizable in economic terms: The DID coefficients in Columns III and IV suggest an additional increase in average long-term debt ratios of 2.5 and 1.6 pp for firms with relatively high ex-ante portfolio values, equal to a 20% and 13% increase relative to the average pre-treatment long-term debt-to-asset ratios of 12.291 for firms with valuable patent portfolios (see Table 3, Panel B). For robustness, we also use the time-variant patent measures ($PVal_{it}$) instead of the $PVal^{pre,high}$ indicator (Columns V and VI). Again, the coefficients of the

interaction terms are positive and statistically significant for both portfolio value definitions.¹²

Panel B of Table 5 uses different specifications of the dependent variable to emphasize the workings of the baseline results. First, estimates in Columns I and II show that the main effect also applies when using the logarithm of long-term debt and the year-over-year growth rate in long-term debt as dependent variables. These results illustrate that the Enforcement Directive raised firms' use of debt financing and did not merely change their composition of debt and assets. Second, estimates in Column III show that the effect on the total debt-to-asset ratio is more moderate and only weakly significant. Consistently, we find no statistically significant effect of the Enforcement Directive on firms' short-term debt financing activities (Column IV). These findings corroborate the view that patents enhance firms' debt capacity in terms of long-term debt (e.g., Mann 2018) and that risky, intangible-rich borrowers rather use short-term than long-term debt (Lim et al. 2020). Hence, they emphasize the workings of the Enforcement Directive in the context of debt financing, i.e., more rigorous patent enforcement reduces the risk associated with patents, facilitating long-term debt financing. Third, estimates in Columns V and VI show that the Enforcement Directive does not significantly affect equity financing. This finding mirrors that sample firms are mostly mature but private firms, for which common external equity financing modes, such as venture capital or public share issues, are less relevant.¹³

Furthermore, we underline the importance of considering the patent portfolio value when evaluating the effect of patenting on firms' financing activities. To illustrate this, Fig. 3 plots the DID estimators from regressions that estimate Equation (4) but use different patent-based

¹² Furthermore, the results are robust to using a continuous treatment variable ($Post^{continuous}$), as displayed in Panel A of Table IA6 (Internet Appendix A). The measure equals the fraction of jurisdictions that have already implemented the Enforcement Directive and in which the patents of respective firms are active. This measure addresses the concern that patents are held (and enforced) across jurisdictions while the adoption of the directive is country-time specific. Moreover, Panel B of Table IA6 shows that the main results are not driven by a few firms with a very high number of patents.

¹³ As displayed in Table 3, more than 80% of sample firms are eight years or older, and about 92% of the sample are private firms. These findings are robust to using alternative definitions of patent portfolio value (see Panel C of Table IA6).

Table 5
Baseline regressions.

Panel A: Capital structure determinants and patenting						
Dependent variable:	Long-term debt ratio					
	(I)	(II)	(III)	(IV)	(V)	(VI)
Post	0.820*** (0.301)	-0.418 (0.386)				
Post × PVal ^{pre, high}		2.251*** (0.668)	2.469*** (0.656)	1.557** (0.654)		
Post × PVal _{t-1}					16.777*** (5.278)	19.480** (9.424)
PVal _{t-1}	4.423 (4.603)	5.949 (5.143)	7.388 (5.041)	-5.605 (13.127)	-0.025 (4.052)	-13.081 (12.679)
Firm size	-0.266 [†] (0.151)	0.621 (0.395)	0.965 [†] (0.521)	0.962 [†] (0.522)	0.967 [†] (0.523)	0.952 [†] (0.523)
Profitability	-5.697*** (1.843)	-5.897*** (2.024)	-5.417*** (1.953)	-5.381*** (1.949)	-5.548*** (1.947)	-5.403*** (1.952)
Tangibility	18.417*** (1.560)	17.007*** (2.029)	15.030*** (2.034)	14.958*** (2.037)	15.086*** (2.026)	15.039*** (2.032)
Cash flow	-13.301*** (1.975)	-11.355*** (2.054)	-11.302*** (2.019)	-11.367*** (2.023)	-11.184*** (2.017)	-11.366*** (2.024)
Constant	15.326*** (1.535)	5.993 (3.887)	2.801 (5.119)	3.169 (5.126)	3.040 (5.139)	3.399 (5.140)
PVal definition:	Eq. (1)	Eq. (1)	Eq. (1)	Eq. (2)	Eq. (1)	Eq. (2)
Additional controls:						
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes	Yes	Yes
R ²	0.12	0.69	0.70	0.70	0.70	0.70
Observations	28,521	28,521	28,521	28,521	28,521	28,521

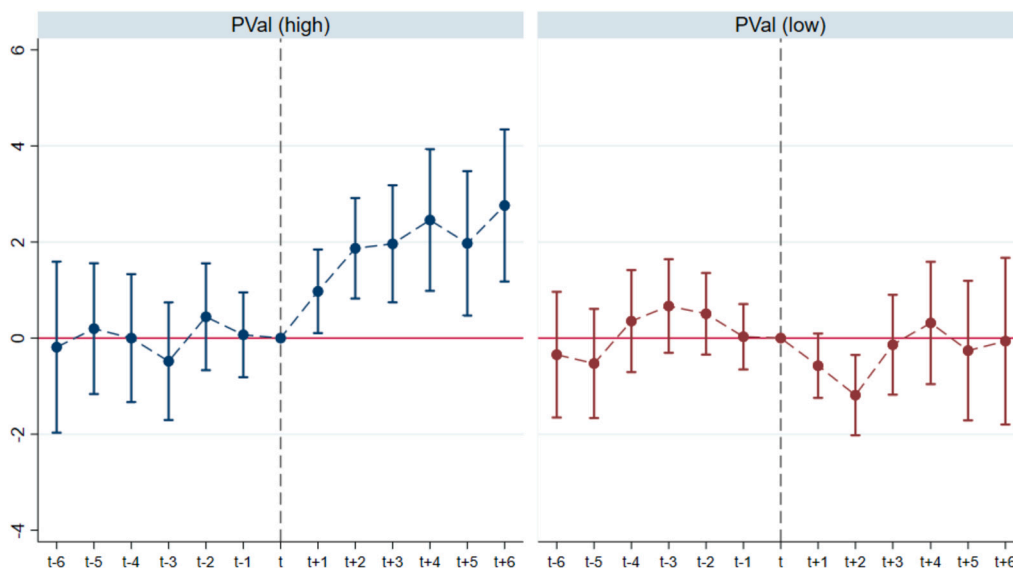
Panel B: DID estimators: Alternative outcome variables on financing activities						
Dependent variable:	log(long-term debt)	Long-term debt growth	Debt ratio (total)	Short-term debt ratio	log(equity)	Equity ratio
	(I)	(II)	(III)	(IV)	(V)	(VI)
Post × PVal ^{pre, high}	0.325*** (0.108)	0.380** (0.178)	1.213 [†] (0.689)	-0.792 (0.497)	-0.080 (0.075)	-0.003 (0.006)
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	0.77	0.20	0.75	0.74	0.87	0.78
Observations	28,521	20,152	28,521	27,577	28,521	28,521

Notes: Panel A presents estimates from regressions explaining the effect of the Enforcement Directive on firms' use of debt, taking into account their patenting activities. The dependent variable is the debt to asset ratio. Firm-level control variables are defined in Table IA5 (Internet Appendix A). Column I estimates Equation (3). Columns II is similar to this but adds firm fixed-effects and the interaction term Post × PVal^{pre, high}. Columns III and IV estimate Equation (4) and only differ in their use of patent portfolio value measures referring to patent stock (Equation (1)) and patent costs (Equation (2)), as indicated at the bottom of the Table. In Columns IV and V, we exchange the binary ex-ante patent value indicator (PVal^{pre, high}) with the continuous, time-varying measures of patent stock and patent costs (PVal_{t-1}), measured at the beginning of the period. Panel B displays estimates on regressions equivalent to Column III in Panel A. Only here the dependent variables are the logarithm of total long-term debt (Column I), the year-over-year growth in long-term debt (Columns II), the total debt-to-asset ratio (Column III), the short-term debt-to-asset ratio (Column IV), the logarithm of total equity (Columns V), and the total equity-to-asset ratio (Columns VI). Panel C of Table IA6 (Internet Appendix A) shows the same set of estimations, using patent portfolio values measured in terms of patent costs (Equation (2)). Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

definitions to determine the responsiveness of firms to the Enforcement Directive. As a benchmark, the first rows graphically illustrate the main results, displaying the DID estimators from Column III in Table 5. We then use the two components of this patent measure separately: the number of active patents (second row) and the number of designated jurisdictions (third row). Previous literature interprets the number of active patents and the number of designated jurisdictions as approximations for the size and value of patenting activities, respectively (e.g., de Rassenfosse and Jaffe 2018). Indeed, the point estimates are positive and significant, but they are smaller and less precisely estimated compared to their combined use. This result suggests that size and value are essential complements for the effect of patenting on firms' ability to

attract debt financing. In row four, we use pre-treatment patent applications as an alternative treatment definition. Here, the DID estimator turns small and insignificant.

Robustness of the staggered treatment estimates: Next, we address methodological concerns regarding the staggered treatment. In principle, the specific adoption process of the Enforcement Directive across EU member states strengthens our empirical approach, as it is one argument for quasi-random assignment of the country-specific timing of the treatment (see Section 2). However, recent literature raises concerns regarding the interpretation of staggered DID analyses since firms in early-adopting member states can act as effective comparison units



The graphs plot the coefficients $\beta_{t+\tau}^{high}$ (left) and $\beta_{t+\tau}^{low}$ (right) for all $\tau \in [-6, 6]$ estimated separately in:

$$Long\text{-}term\ debt\ ratio_{ict}^s = \sum_{\tau=-6}^6 \beta_{t+\tau}^s PVal_{it}^{pre,s} + \beta^i CS_{it} + \varphi_i + \delta_{ict} + \varepsilon_{ict}, \text{ with } s \in [high, low].$$

Notes: These figures plot coefficients from estimations explaining firms’ long-term debt ratios relative to the implementation of the Enforcement Directive. The regression specification is denoted below the table and variables are defined equivalent to the baseline specification from Equation (4). In addition, this specification includes a set of interactions of year dummies with a dummy indicating firms ex-ante patent portfolio value: $PVal_{it}^{pre,s}$ with $s \in [high, low]$ is a dummy variable equal to one if firm i has an ex-ante patent portfolio value above ($s=high$) or below ($s=low$) the median in year τ relative to the implementation of the Enforcement Directive in the home country of firm i , and zero otherwise. Value refers to the patent portfolio cost measure as defined in Equation (2). Whiskers span the 90 percent confidence intervals.

Fig. 4. Coefficient plot: lag structure of the treatment effect.

whose response to the treatment may affect late-adopting observations (Goodman-Bacon 2021). In our baseline specification, late adopters (or: “not-yet- or last-treated units” according to Baker et al. 2022) essentially act as a comparison group after early adopters are treated. The share of never-treated units is high in our setting, and the treatment occurs across a fairly narrow timespan. In such cases, the biases associated with staggered DID regressions are unlikely to be severe (Baker et al. 2022).

Still, to further mitigate methodological concerns, we implement several tests. First, we investigate the lag structure of the results using an event-study design to assess the timing of the effects in more detail. Fig. 4 plots the coefficients of the interactions between the $PVal_{it}^{pre,high}$ indicator and country-specific year dummies using a symmetrical time window of six years around the country-specific adoption of the Enforcement Directive. This specification is a stacked regression, following Sun and Abraham (2021), that excludes the earliest and latest periods from the estimations (i.e., those more than six years before or after the treatment year) to avoid biased estimates in our two-way fixed effects DID setting. Estimates in the pre-treatment period are small and insignificant for all firms, irrespective of their ex-ante patent portfolio characteristics. Importantly, the paths of these two groups diverge after the transposition of the Enforcement Directive. Only firms with high portfolio values raise their long-term debt ratios, starting in the country-specific year after the change in the law. This pattern is robust to using alternative definitions of the $PVal_{it}^{pre,high}$ measure similar to Fig. 3 (see Panel A of Table IA7 in Internet Appendix A).

Second, we decompose the main effects for early- and late-adopting firms. We cannot use the standardized decomposition, as suggested in Goodman-Bacon (2021), because our data is structured in an unbalanced panel. Instead, we reestimate the baseline estimates for split samples of early- and late-adopters, i.e., firms in countries that implemented the Enforcement Directive before and after 2008. Results for these two groups displayed in Panel B of Table IA7 (Internet Appendix A) are very similar: While the average effect of the amendment is higher

for early adopters compared to late adopters (9.438 versus 6.147), the estimates of early adopters are less precise (see Columns I and III). In both cases, firms with high ex-ante portfolios are disproportionately affected (see Columns II and IV).¹⁴ We combine the previous two aspects and run stacked regressions with and without time-varying covariates (Columns V-VIII) as proposed in Cengiz et al. (2019). Again, we do not bin the observations at the borders of the sample. Estimates are qualitatively similar to our baseline findings.

Third, we follow the suggestion of Baker et al. (2022) and show that there are no differential anticipatory effects between treated and control group firms in late-adopting countries. To mitigate concerns about disproportional anticipatory effects in late-adopting countries, we reestimate Fig. 4 on the subsample of these countries. The coefficient plot in Panel C of Table IA7 shows no (differential) anticipatory effects throughout the country-specific pre-treatment period. Note that this does not imply that late-adopting countries did not anticipate the change in law, per se. However, vital for our identification strategy, these results mitigate concerns that there are differential anticipatory effects comparing firms with high and low ex-ante patent portfolio values that bias our results. In sum, we find robust evidence that the staggered treatment DID design is unlikely to suffer from biased estimates.

4.2. Exploiting heterogeneity in treatment intensities

The main analysis in Section 4.1 implicitly assumes homogeneous treatment intensities across EU countries. The following analyses relax this assumption and test country- and industry-specific heterogeneity in the treatment intensity. The estimates thereby address identification

¹⁴ Coefficients can be directly compared since the difference in average pre-treatment long-term debt ratios among the two groups of firms is statistically insignificant (14.45 and 14.70, t-value: 0.017).

concerns and simultaneously deliver further important insights into the role of patenting activities in attracting debt financing.

Different degrees of legislative changes: First, we exploit heterogeneity in the number of amendments to the existing domestic legislation across countries. To this end, we assess the comprehensive evaluation study of the Enforcement Directive by Petillion (2019). The study covers analyses from legal practitioners in each EU member state, enabling us to quantify the degree of legal changes country by country. For each Article of the Enforcement Directive, the reviews explicitly state whether (i) no changes have been made towards meeting the requirements by 2018, (ii) minor adjustments were made, implying that the legislative setting is at least partially based on the pre-Directive legislation, or (iii) amendments were introduced that substantially impacted legislation or legislation was newly added.¹⁵ Panel A of Table 6 displays the number of partial and full amendments for each sample country, visualizing the degrees of adjustment to the national legislative systems.

We start by showing that the overall effects are more pronounced in countries with more extensive adjustments. Panel B of Table 6 displays regressions that use the actual number of amendments as a continuous treatment variable ($Post^{Amd, count}$). Specifically, Columns I-III are equivalent to Columns I-III of Table 5 but use $Post^{Amd, count}$ instead of the original $Post$ -dummy. The estimates are consistent with the baseline estimates. The highly significant, positive coefficient in Column I suggests an increase of patenting firms' long-term debt ratios by 0.851 for each fully adopted Article in the Enforcement Directive. This result implies that the effect of the Enforcement Directive on debt ratios is about twice as strong in high-adoption countries compared to low-adoption countries. As such, countries with low adoption rates implemented only two main articles (e.g., Belgium or Finland), while countries with high adoption rates implemented five or six articles (e.g., Germany or Denmark).

To test the robustness of this finding, we reestimate the baseline specification on subsamples with a high and low degree of legislative changes separately. We consider adjustments to be relatively high once the respective country fully implements the median number of at least five Articles. Columns IV-VII of Table 6 (Panel B) display estimates on regressions equivalent to the baseline estimations (Columns I and III in Table 5) using split samples. In both cases, the coefficients are positive and highly significant. However, the size of the coefficients is again about twice as large for countries with a higher number of amendments (2.618 versus 1.135 and 4.757 versus 2.289, respectively). To confirm that these differences are statistically significant, Column VIII uses the full sample and adds a triple interaction term in which a dummy for countries with many amendments (Amd^{high}) is multiplied with the term $Post \times PVal^{pre, high}$. Again, the coefficient is positive and significant at the five percent level, indicating a disproportionately positive effect of the Enforcement Directive on the long-term debt ratios of firms in countries with relatively more legal amendments. These estimates emphasize that the changes in debt financing of patenting firms can be linked to the actual changes to domestic law, i.e., the strength of the legal change.

Competition-induced responsiveness: As a second dimension of heterogeneous treatment intensity, we introduce firm-specific variation in the responsiveness to the Enforcement Directive. Amendments in patent enforcement law are likely to have different effects depending on firms' competitive environment prior to the law change. Strengthening patent enforcement should be most relevant for firms operating in more competitive environments (e.g., Aghion et al. 2015). In such environments,

¹⁵ Out of the 22 articles, we consider all articles as relevant that do not have mere administrative purposes (Articles 1-3 and Articles 16-22) or that are suggestions (Article 12). Table IA8 (Internet Appendix A) lists the country-specific amendments for each Article in each EU15 country in a country-Article matrix.

the improved position relative to competitors is more valuable compared to less competitive environments as differentiation is more important and, thus, can lead to additional returns in expectation.

To quantify competition, we follow the literature and compute ex-ante industry-level competition measures based on aggregated firm-level markups (e.g., Aghion et al. 2005; Bajgar et al. 2019). This approach addresses concerns that firm-level markups are endogenous to business operations while more aggregate markups are less likely to be affected by individual firm-level activities. Specifically, we calculate markups (μ_{it}) of firm i in year t during the final, country-specific year before the Enforcement Directive implementation: $\mu_{it} = \frac{sales_{it}}{opex_{it}}$, where $sales_{it}$ are the total sales during the period, and $opex_{it}$ are total operating expenses of respective firms. Higher markups indicate stronger market power and imply a weaker competitive environment and vice versa. We use the entire population of ORBIS firms (including out-of-sample firms) to calculate country-industry-specific averages of μ_{it} . ORBIS data comprises a large enough group to define granular industry levels of aggregation, i.e., on the NACE 4-digit level. We deploy different thresholds to determine high and low competitive environments in the distribution of country-industry average markups. Using these thresholds, we test whether differences in ex-ante competition levels explain differences in the responsiveness to the Enforcement Directive.

Panel A of Table 7 displays estimates equivalent to the baseline specification but using subsamples of firms operating in fields with high and low competition, respectively. Here, firms are defined to face high or low competition once they belong to an industry in the top (bottom) quartile of the ex-ante competition distribution. There is no statistically significant difference in the mean of the dependent variables for these groups (18.73 and 18.48; t-value: 0.58). We estimate positive significant effects for the $Post$ -dummy in each group. The size of the effects is comparable in magnitude (3.932 and 4.033, Columns I and IV), indicating that the average patenting firm reacts to the Enforcement Directive irrespective of its competitive environment. However, for firms in highly competitive environments, the Enforcement Directive has a positive disproportional effect on their long-term debt ratios (Columns II and III). The DID estimators are positive and highly significant. Conversely, for firms in low-competition environments, the interaction terms are much smaller and insignificant (see Columns V and VI). Hence, the patent portfolio value is pivotal once firms face fierce competition.

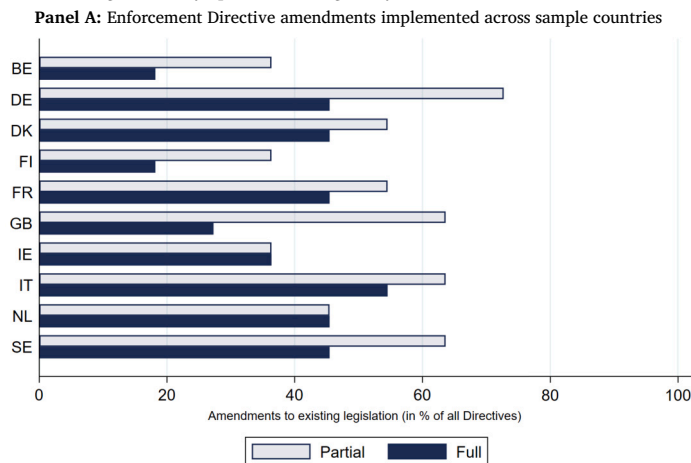
We move one step further and split the sample into five equally-sized groups along the competition distribution to reestimate the specifications of Columns I and III from Panel A for each group. The coefficient plot in Panel B of Table 7 confirms the previous insight that increases in debt ratios are most pronounced for firms in more competitive industries. We find disproportional positive effects for firms with high-value patent portfolios only in industries with relatively high competition. This finding is consistent with the idea that differentiation among competitors may be particularly relevant in competitive environments, and valuable patent portfolios might deliver a significant competitive advantage. In such cases, enhanced patent enforcement may disproportionately reinforce firms' competitive position and eventually improve borrowing conditions.

4.3. Testing potential threats to identification

4.3.1. CEM matching approach: patenting versus non-patenting firms

Despite all previous robustness tests, it may still be the case that omitted factors related to differences between firms with high and low patenting intensities confound the main results. This section addresses this issue by presenting an alternative estimation approach using a matched sample. The idea is to obtain a control group with similar observable firm characteristics but for which the Enforcement Directive was irrelevant, such as non-patenting firms. Hence, in this approach, we pair patenting firms from the main sample with non-patenting, out-of-sample firms. As a positive side effect, this approach further moderates

Table 6
The degree of legislative change: Country-specific heterogeneity in the treatment effects.



Panel B: Regression estimates considering the heterogeneous degrees in the legislative change

Dependent variable:	Long-term debt ratio							
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Post ^{Amd_count}	0.851 ^{***} (0.105)	-0.071 (0.114)						
Post ^{Amd_count} × PVal ^{pre, high}		0.690 ^{***} (0.195)	0.746 ^{***} (0.190)					
Post				2.618 ^{***} (0.645)	1.135 ^{**} (0.592)			
Post × PVal ^{pre, high}						4.757 ^{***} (1.202)	2.289 ^{**} (1.023)	1.759 ^{**} (0.775)
Post × PVal ^{pre, high} × Amd ^{high}								2.873 ^{**} (1.430)
Sample: degree of leg. change:	All	All	All	High	Low	High	Low	All
Additional controls:								
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	No	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	No	No	Yes	Yes	Yes
R ²	0.09	0.12	0.10	0.08	0.10	0.66	0.73	0.70
Observations	28,521	28,521	28,521	8,599	11,861	8,599	11,861	28,521

Notes: In Panel A, we plot the country-level share of Articles from the Enforcement Directive that were at least partially or fully amended. We hand-collect information on the implementation status from Petillion (2019) and classify the implementation status accordingly (see Section 4.2). Table IA8 (Internet Appendix A) displays the status of adoption on the basis of each Article for each EU 15 country. Panel B present estimates from regressions explaining the effect of the Enforcement Directive on firms' long-term debt ratios. Columns I-III are equivalent to Columns I-III in Table 5 only here the *Post* indicator is exchanged with the *Post^{Amd_count}* which is zero for all years prior to the country-specific adoption of the Enforcement Directive and is equal to the number of fully adopted articles of the directive thereafter. The original score ranges from 2 to 6. To ease the interpretation, this count is linearly transformed such that the lowest and highest number of full amendments receive the values 1 and 5, respectively. Columns IV and V and Columns VI and VII are equivalent to Columns I and III in the baseline regressions but are estimated on subsamples of countries with high and low degrees of legislative change. A country exhibits high change to the domestic legislation if the adjustment score (see Table IA8) is above the median of 11 amendments and low changes if the adjustment score is below 11. Countries with 11 amendments are not considered to experience high or low legislative changes. Column VIII repeats the estimations from the previous two columns but uses the full sample and adds a triple interaction term ($Post \times PVal^{pre, high} \times Amd^{high}$), where *Post* and *PVal^{pre, high}* are defined as before and *Amd^{high}* is an indicator equal to one if a firm is located in a country with a high degree of legislative change. Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

potential biases associated with staggered DID regressions since it includes a large share of never-treated firms by definition.

The original ORBIS dataset contains abundant non-patenting matching candidates. As a prerequisite, firm pairs must share the same country and industry (NACE Rev. 2 main category). In addition, patenting and non-patenting firms have to feature similar financial characteristics during the pre-treatment period regarding the key capital structure determinants (see Equation (3)), their debt ratios, and age categories. We match patenting and non-patenting firms based on the pre-treatment mean values of these characteristics, using Coarsened Exact Matching

(CEM).¹⁶ This procedure eventually results in a sample of 17,708 firm-year observations, out of which 8,389 (9,316) observations are patenting (non-patenting) firms. Summary statistics in Panel A of Table 8 show

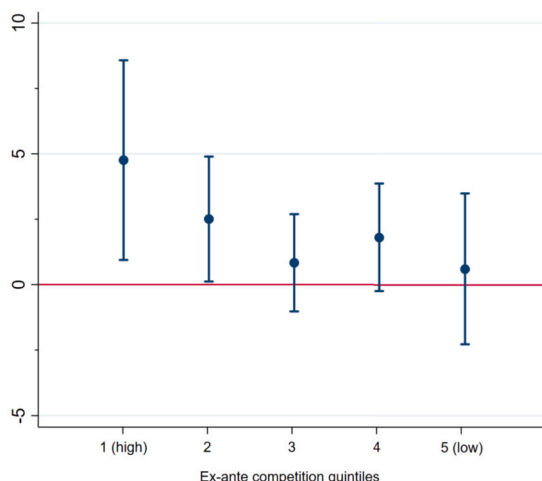
¹⁶ Cut-offs of the age categories are: ≤2, 3-5, 6-10, 11-15, 16-25, 26-50, and 51-100 years. We use 30 equally-sized bins for continuous matching variables. If a firm falls into a strata without a matching partner, it is not considered for the analysis.

Table 7
Industry-specific heterogeneous treatment effects: Firms' competitive environment.

Panel A: Regression estimates considering the heterogeneous degrees in ex-ante competition

Dependent variable:	Long-term debt ratio						
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
Post	3.285*** (0.865)	-0.931 (1.049)		4.049*** (0.753)	0.902 (0.799)		
Post × PVal ^{pre, high}		4.224*** (1.573)	3.848** (1.588)		1.043 (1.314)	0.698 (1.243)	0.858 (0.871)
Post × PVal ^{pre, high} × Comp ^{low}							0.224 (1.531)
Post × PVal ^{pre, high} × Comp ^{high}							3.590* (1.867)
Ex-ante competition:	Highest			Lowest			Any
Additional controls:							
Firm-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	No	Yes	Yes	Yes
Country-Year FE	No	No	Yes	No	No	Yes	Yes
R ²	0.16	0.69	0.71	0.09	0.69	0.71	0.70
Observations	4,517	4,517	4,517	8,009	8,009	8,009	28,312

Panel B: Coefficient plots of the DID estimator for Post × PVal^{pre, high} across competition quintiles



Notes: Panel A presents estimates from regressions explaining the effect of the Enforcement Directive on firms' long-term debt ratios equivalent to Columns I-III in Table 5; only here the sample is firms that face particularly high (Columns I-III) or low (Columns IV-VI) levels of competition prior to the implementation of the Enforcement Directive. Highly competitive environments are in the top quartile of the country-industry specific distribution of competition, while low competitive environments are in the bottom quartile. Competition is defined by the firm-specific markups as discussed in Section 4.2. The estimation in Column VII uses the full sample but includes triple interactions of the term Post × PVal^{pre, high} multiplied with an indicator for firms in low (Comp^{low}) and high (Comp^{high}) competition environments. Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level. Panel B displays the coefficients for the Post × PVal^{pre, high} variable obtained from the baseline specifications, i.e., β₁ in Equation (4). PVal^{pre, high} is measured using the patent costs variable. Coefficients are ordered by the competition intensity, ranging from the highest (top 20%) to lowest (bottom 20%) quintile. Whiskers span the 95 percent confidence intervals.

that the two groups of firms are comparable along observable firm characteristics.

We estimate the following equation to explain the effect of the Enforcement Directive on the long-term debt ratios of patenting firms relative to the group of comparable non-patenting firms:

$$\begin{aligned}
 \text{Long-term debt ratio}_{i\text{cnt}} = & \gamma_1 \text{Patenter}_i + \gamma_2 \text{Post}_{ct} + \gamma_3 (\text{Patenter}_i \times \text{Post}_{ct}) \\
 & + \gamma_4 \text{CS}_{it} + \gamma_{cn} + u_{i\text{cnt}},
 \end{aligned}
 \tag{5}$$

with the dummy variable, Patenter_i, indicating whether firm *i* belongs to the group of ex-ante patenting firms. γ_{cn} are country-industry fixed effects. The remaining variables are specified as defined in Equation (4).

Hence, γ₃ is the coefficient of interest and captures the additional effect of the Enforcement Directive on the long-term debt ratios of patenting firms relative to non-patenting firms.

Panel B of Table 8 contains estimates on different variants of this setting. Column I displays estimates on the variables Post and Patenter and shows a positive effect of the Enforcement Directive on firms' debt ratios. The effect is less precisely estimated than the baseline results, reflecting that the Post variable captures the average treatment effect on patenting (affected) and non-patenting (unaffected) firms. Importantly, we find that patenting firms disproportionately increase using long-term debt relative to non-patenting firms in response to the amendments. As such, the coefficient of the interaction term Post × Patenter in Col-

Table 8

Non-patenters as controls: The Enforcement Directive's effects on patenting firms.

Panel A: Firm-level characteristics of patenting and matched, non-patenting firms						
	Patenting		Non-patenting		Difference in means	
Debt ratio (in %)	9.599		8.795		0.804	
Firm size	8.083		8.044		0.039	
Profitability	0.131		0.124		0.007	
Tangibility	0.125		0.125		0.000	
Cash flow-ratio	0.096		0.092		0.004	
Employees (#)	199		180		19	
Age	20.8		20.6		0.2	
Quoted (in %)	1.566		1.620		-0.016	

Panel B: DID regressions explaining the treatment effect for patenting vs. non-patenting firms						
Dependent variable:	Long-term debt ratio					
	(I)	(II)	(III)	(IV)	(V)	(VI)
Post × Patenter		1.918** (0.847)	1.555** (0.775)		0.898 (1.007)	0.200 (0.998)
Post	0.765* (0.412)	0.122 (0.517)		0.158 (0.448)	-0.001 (0.482)	
Patenter	0.806 (0.777)	0.467 (0.796)		0.529 (0.982)	-2.944* (1.737)	
Sample:	Matched sample			Placebo sample		
Additional controls:						
Firm-level	No	Yes	Yes	No	Yes	Yes
Country-Industry FE	No	Yes	No	No	Yes	No
Firm FE	No	No	Yes	No	No	Yes
Country-Year FE	No	No	Yes	No	No	Yes
R ² (within)	0.001	0.03	0.08	0.0001	0.03	0.09
Observations	10,265	9,226	9,226	8,610	7,630	7,630

Notes: Panel A displays the pre-treatment mean values of key, firm-level variables from the matched sample as described in Section 4.3.1, distinguishing among pre-treatment patenting and non-patenting firms. All variables are defined in Table IA5 (Internet Appendix A). Note that none of the differences in means is statistically significant (t-values are not displayed). Panel B presents estimates from regressions explaining firms' long-term debt ratios. Columns I-III use the sample of matched firms, which contains patenting and non-patenting firms. *Post* is the country-specific indicator for the implementation of the Enforcement Directive. The indicator *Patenter* equals one (zero) if a firm files at least one patent prior to the implementation of the Enforcement Directive in the firm's respective home country. Column I estimates the effect of the two regressors *Patenter* and *Post* on firms' use of debt. Column II estimates Equation (5) and additionally includes the interaction of the two variables, firm-level controls (as in previous regressions), and country-industry fixed-effects. Column III adds firm and country-year fixed effects, which causes *Patenter*, *Post*, and the country-industry fixed effects to drop due to perfect multicollinearity. Columns IV-VI repeat the first three estimations but use a placebo sample that includes patenting firms, which only filed patents after the implementation of the Enforcement Directive (but not before), and their matched counterparts. Again, all regressions control for firms' patent portfolio values. Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Column II is positive and significant. Relative to their average long-term debt ratio in Panel A, the coefficient (1.918) implies that patenting firms increase their debt ratio by about 20% (or 1.9 pp) relative to the non-patenting group. The coefficient of *Patenter* is statistically insignificant, indicating comparable pre-treatment debt ratios of patenting and non-patenting firms in the matched sample. These results are robust to applying firm and country-year fixed effects (Column III).

Columns IV-VI repeat these three specifications for a different sample in which we condition patenting firms not to have filed patents before the country-specific adoption of the Enforcement Directive but only thereafter. These firms are a suitable placebo group because they are known with certainty not to hold any patents at the time of the change in law.¹⁷ Across specifications and in line with our empirical strategy, we find no statistically significant effects of the Enforcement

Directive on long-term debt ratios. These results underline that firms only respond to the directive if patenting is relevant to them. The above results thus mitigate concerns that biases arising from observable differences in firm characteristics or staggered DID regressions account for our main results.

4.3.2. The timing of the treatment and demand-side effects

The Great Financial Crisis: This section addresses concerns that other omitted factors unrelated to the Enforcement Directive drive the main results. First, we acknowledge that the treatment period encloses the Global Financial Crisis (GFC), which unfolded in late 2008 and stifled economic activities in Europe. This coincidence may be problematic for our empirical strategy, for example, since inventive activities could be related to the financial health of respective firms, helping them to obtain debt financing. In this case, the increased use of debt of firms with (valuable) patent portfolios during the mid-2000s could be due to the GFC and not the strengthened patent enforcement laws.

¹⁷ Firms that are never observed to file any patents may be false negatives if the ORBIS-PATSTAT match was erroneous.

To show that the GFC is unlikely the driver behind the main results, we test the competing hypothesis: If the crisis is better at explaining the main results, we expect to obtain larger - or at least similar - point estimates relative to baseline results. We, therefore, mimic the baseline regressions displayed in Table 5 but exchange the *Post* dummy with a crisis indicator (*GFC*).¹⁸ Column I of Table IA9 (Internet Appendix A) shows a positive and significant effect of the crisis-dummy years on the long-term debt ratios of the patenting firms, which is unsurprising because the crisis period entirely overlaps with the original post-treatment period. However, the magnitude and precision of the estimate is weaker (0.532) compared to the baseline effect (0.820). Moreover, the positive effect vanishes when interacting the GFC indicator with the $PVal^{pre,high}$ dummy (Columns II and III). Similarly, when reintroducing the original DID interaction (Columns IV and V), the positive effect is solely attributed to the $Post \times PVal^{pre,high}$ interaction (i.e., the Enforcement Directive). In sum, these estimates indicate that the immediate recession period in the respective countries is unlikely to account for the baseline results.

Furthermore, we show that survivorship biases are unlikely to confound the main results. Indeed, the crisis may have screened out underperforming firms with lower debt capacities, leaving only financially healthy ones to survive. ORBIS data does not contain information on insolvencies. However, 80% of the sample firms appear in each year between 2007 and 2012, suggesting that these firms survived the crisis with certainty. Thus, we test if estimations on the subsample of surviving firms yield different results than the baseline regressions. Figure IA4 (Internet Appendix B) plots the DID estimators obtained from the baseline estimates and those obtained from regression using a subsample in which firms have at least five observations between 2007 and 2012. Using different $PVal^{pre,high}$ definitions, equivalent to those in Fig. 3, shows that DID estimators are very similar in magnitude and significance, emphasizing that our main results are unlikely to be driven by crisis-related survivorship factors.

Furthermore, we show that the Enforcement Directive's implementation led to changes in patenting firms' financing activities rather than the announcement of the amendment. The directive was finalized and published by the European Parliament and the Council on April 29th, 2004. However, it became effective across EU member states at different times throughout the subsequent five years. Prior literature finds that dynamics in the strength of the IP system originate from the actual implementation but not from the confirmation of the change itself (e.g., Papageorgiadis and Sofka 2020). Indeed, Columns VI and VII of Table IA9 (Internet Appendix A) confirm that the mere announcement of the Enforcement Directive cannot be associated with a change in patenting firms' use of debt.¹⁹ We also find that treated firms did not adjust patenting behavior in response to the announcement in terms of patent filings (Columns VIII and IX) or regarding their patenting expenditures (see Panel B of Table IA9).

Demand side effects: Next, we demonstrate that demand-driven mechanisms are unlikely to account for the main results. This is important since the empirical strategy treats the Enforcement Directive as an exogenous shift in the loan supply. Yet, it is well-established that firms' capital structure decisions are jointly determined by supply- and demand-side factors (e.g., Bolton and Freixas 2000; Avezum et al.

¹⁸ Following literature (e.g., Laeven and Valencia 2013), we operationalize the crisis using a dummy variable (*GFC*) that equals one if the home country of a firm experiences a recession in any given period, i.e., once real GDP growth is negative and unemployment rates increase for at least two consecutive quarters.

¹⁹ Specifically, we use a sample that excludes years in which the directive was active and reestimate the baseline specification using a treatment variable ($Post^{2004}$), which is equal to one for all country-years between the announcement and transposition to domestic legislation, and zero otherwise. The estimations yield statistically insignificant interaction terms.

2022). Previous regressions include different sets of fixed effects to control for variation in aggregate loan demand. Nevertheless, it can be the case that the financing demand of firms changed throughout the sample period, for example, due to the financial crisis and the subsequent European debt crisis. These crises may have particularly affected specific business models reliant on innovative activities, hampering their profitability and internal funding. While the previous section shows that the GFC did not *immediately* affect debt ratios, it does not preclude that it had more permanent effects.

We test two hypotheses to investigate the potential role of changes in firms' loan demand on the baseline estimates. First, if our estimation approach (i.e., the DID estimator) captures changes in loan demand that bias the main results, the baseline specification in Equation (4) should explain variation in observable factors that reflect the demand for external debt financing. Such factors include profitability, liquidity, or internally generated funds. Second, if changes in demand factors are omitted variables that bias the main results, the positive impact of the Enforcement Directive on long-term debt ratios may be driven by firms for which we observe changes in demand factors.

Table IA10 (Internet Appendix A) displays estimates on regressions that test these two hypotheses. Regarding the first hypothesis, estimates in Panel A of Table IA10 show that the Enforcement Directive did not have measurable effects on observable firm-level factors that reflect the demand for external debt financing. Specifically, we repeat the baseline estimations for both patent value measures using three dependent variables: profitability, the current ratio, and cash holdings. The DID estimators for regressions explaining changes in any of these four factors are small and insignificant.²⁰

Regarding the second hypothesis, estimates in Panel B of Table IA10 illustrate that the positive impact of the Enforcement Directive on long-term debt ratios cannot be attributed to firms that exhibit changes in factors reflecting an increased loan demand. To show this, we identify firms with lower levels of profitability, measured by the return on assets, after 2008 compared to before. This specification assumes that firms with a significant decline in profitability due to the financial crisis must have a higher demand for external financing. We repeat the baseline estimation separately for firms that experienced such an increase and those that did not. The baseline effects are similar for firms irrespective of their change in profitability (i.e., loan demand) during the crisis years after 2008 (Columns I and II). For robustness, we also deploy a regression that includes triple interactions using different variable specifications, including a continuous measure of profitability. Across specifications, we find no support for the view that firms with an increased loan demand drive the main results. In sum, these analyses yield a coherent picture as we can reject the two hypotheses, which suggest that shifts in the demand for loans are an omitted factor driving the main results.

5. Leveraging patents and financing conditions

5.1. Who benefits from stronger patent right enforcement?

Legal status, age, and firm size: This section discloses several firm-level characteristics that increase the responsiveness to the Enforcement Directive. These analyses build on the idea that firms with limited access to financial resources are more responsive to variation in their access to external debt (see Holmström and Tirole 1997). Specifically, we first consider firm size-related characteristics as decisive for firms' access to finance, i.e., we estimate differential effects between i) private and

²⁰ The current ratio and cash holdings are measured as a fraction of current liabilities (see Table IA5 in the Internet Appendix A). The finding is robust to using an alternative treatment indicator to the *Post* variable in the main specification, i.e., a dummy that equals one for all years after 2008 and zero otherwise as (undisplayed).

Table 9
Heterogeneity in the response to the treatment: firm characteristics.

Dependent variable: Long-term debt ratio												
Panel A: Heterogeneous treatment effects												
Sample criteria:	Access to stock market				Firm age				Firm size			
Subsample:	Private		Public		Young		Old		SME		Large	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)
Post	-0.402 (0.409)		-0.884 (1.012)		-0.508 (0.678)		-0.182 (0.483)		-0.441 (0.495)		-0.239 (0.638)	
Post × PVal ^{pre, high}	2.350*** (0.727)	2.559*** (0.713)	1.312 (1.312)	1.408 (1.318)	3.849*** (1.142)	3.920*** (1.132)	1.158 (0.834)	1.158 [†] (0.813)	2.555*** (0.911)	2.464*** (0.911)	1.297 (1.015)	1.474 (0.998)
R ²	0.69	0.70	0.60	0.64	0.70	0.71	0.66	0.67	0.69	0.70	0.66	0.68
Observations	26,345	26,345	2,091	2,091	10,467	10,467	16,708	16,708	18,215	18,215	9,074	9,074
Panel B: Different degrees of ex-ante financing constraints and dependence on external financing												
Constrained criteria:	Young, private SME				S&A index				RZ-score			
Subsample:	Constrained		Unconstraint		Constrained		Unconstraint		Constrained		Unconstraint	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)
Post	-0.513 (1.046)		-0.066 (0.625)		-0.628 (0.649)		-0.146 (0.483)		-0.079 (0.574)		0.200 (0.515)	
Post × PVal ^{pre, high}	3.676** (1.852)	3.634* (1.870)	1.197 (0.997)	1.308 (0.984)	3.266*** (1.022)	3.478*** (1.016)	1.203 (0.901)	1.457 [†] (0.877)	1.903** (0.902)	2.489*** (0.898)	1.500 (0.984)	1.509 (0.958)
R ²	0.70	0.72	0.65	0.67	0.70	0.71	0.64	0.66	0.68	0.69	0.66	0.68
Observations	5,562	5,562	9,416	9,416	12,956	12,956	14,314	14,314	12,551	12,551	12,736	12,736
Additional controls in both panels:												
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Both panels display estimates from regressions that explain the effect of the Enforcement Directive on the use of debt, equivalent to Columns II and III in Table 5. Only here, the samples are split according to firm characteristics measured in the year prior to the country-specific last year before the Enforcement Directive was implemented. Panel A distinguishes private firms and public firms (Columns I-IV), relatively young and old firms, i.e., firms with a below or above median age (Columns V-VIII), and SMEs versus large firms (Columns IX-XII), respectively. SMEs have less than 250 employees and no more than 43 million Euro of total assets. Panel B distinguishes financially constrained and unconstrained firms using three different measures. Columns I-IV differentiates between firms that are private, young, and SMEs and those that are either no SMEs or publicly listed. Columns V-VIII distinguish firms with an above and below median S&A index score during the three pre-treatment years. The S&A index is computed following Hadlock and Pierce (2010). Columns IX-XII distinguish firms with a below or above median RZ-score. The RZ-score is computed following Rajan and Zingales (1998) and measures dependence on external finance. Standard errors (in parentheses below coefficients) are heteroscedasticity-consistent and clustered at the firm level. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

public firms, ii) relatively young and old firms, and iii) SMEs and larger firms. Young firms are below the median age of 18 years. SMEs are classified according to the Eurostat definition of at most 250 employees and a balance sheet total of fewer than 43 million Euros. The reference year to classify firms into these groups is the year before the country-specific implementation of the directive.

Table 9 displays estimations similar to the baseline specifications (i.e., Columns II and III in Table 5), but regressions use the subsamples as defined above. Across specifications and size definitions, the estimates provide a consistent picture: The positive effects of the Enforcement Directive on firms' debt capacity are strongest for private, young, and small firms. More specifically, estimates on the subsamples of private and public firms show significant positive effects on the interaction terms for private firms (Columns I-IV). These results corroborate prior research showing that private firms are typically more responsive to changes in the supply of external debt financing compared to large listed firms that usually have more means to secure external financing (e.g., Beck et al. 2005; Cornaggia et al. 2015). This pattern is very similar for relatively younger firms, as displayed in Columns V-VIII. The disproportional effect for relatively younger firms is consistent with the fact that these firms may have less established bank relationships and, thus, are more responsive to changes in the supply of loans. As the third firm-level characteristic, Columns IX-XII display estimates for SMEs and large firms separately. Results echo the previous findings on the sample split on firms' legal status and age. SMEs with valuable patent portfolios disproportionately respond to the Enforcement Directive compared to their larger counterparts. These results suggest that more vulnerable patenting firms are most responsive to the Enforcement Directive,

potentially reflecting that the legal change alleviated their financing constraints.

To test the robustness of these findings, we add two analyses. First, we repeat the subsample analyses using the treatment variable *Post* measured by the number of amendments to domestic legislation equivalent to Section 4.2. Panel A of Table IA11 (Internet Appendix A) repeats the specifications from Columns III, IV, V, and VIII but for the subsamples of public firms and SMEs. The estimates confirm the previous results, showing that the above-described effects are most substantial in countries with a higher degree of legislative change. Second, we test whether the subgroups of private, young, and small firms disproportionately adjust their financing, irrespective of the type. Specifically, we estimate similar regressions to those in Table 9 but use the logarithm of equity as an alternative outcome (Panel B of Table IA11). Across specifications, the results are insignificant.

Financing constraints: Next, we focus more specifically on financially constrained firms. We approximate the financing conditions of firms before the treatment using three different dimensions. First, we consider young, private SMEs to be relatively more constrained in their access to external financing than large or publicly listed firms. This rather broad approach combines the results from Panel A and is consistent with the literature on small business financing (e.g., Berger and Udell 2006; Carbo-Valverde et al. 2009). As a second measure, we use the S&A index (see Hadlock and Pierce 2010) for identifying constrained firms. Again, the intuition behind this measure is that firms in the earlier phases of their life cycle are particularly constrained in their access to different financing sources, whereas this restriction vanishes as firms mature. Third, we consider the RZ-score (see Rajan and Zingales 1998),

Table 10
DiD estimations: The Enforcement Directive and the costs of obtaining debt.

Dependent variable:	Costs of debt: Interest burden					
	(I)	(II)	(III)	(IV)	(V)	(VI)
Post	-1.365*** (0.146)	-0.896*** (0.178)				
Post × PVal ^{pre, high}		-1.269*** (0.342)	-1.219*** (0.337)	-0.976*** (0.428)	-0.946** (0.368)	-0.735* (0.381)
Post × SME ^{yp}					0.489 (0.431)	0.436 (0.424)
Post × PVal ^{pre, high} × SME ^{yp}					-2.008** (0.870)	-1.801* (0.936)
PVal _{t-1}	-2.428* (1.285)	-1.181 (1.545)	-1.729 (1.465)	-4.780 (6.478)	-1.711 (1.467)	-4.581 (6.443)
Firm size	0.063 (0.052)	-0.492*** (0.181)	-0.821*** (0.240)	-0.829*** (0.241)	-0.818*** (0.240)	-0.836*** (0.241)
Profitability	3.978*** (0.806)	3.728*** (0.928)	3.684*** (0.889)	3.727*** (0.890)	3.648*** (0.891)	3.728*** (0.893)
Tangibility	-3.744*** (0.603)	-2.611*** (0.952)	-2.741*** (0.925)	-2.695*** (0.928)	-2.748*** (0.926)	-2.728*** (0.927)
Cash flow	-4.771*** (0.917)	-4.663*** (1.012)	-4.595*** (1.005)	-4.619*** (1.007)	-4.592*** (1.005)	-4.648*** (1.010)
Constant	13.914*** (0.549)	19.203*** (1.859)	22.177*** (2.451)	22.217*** (2.460)	22.099*** (2.450)	22.261*** (2.458)
PVal definition:	Eq. (1)	Eq. (1)	Eq. (1)	Eq. (2)	Eq. (1)	Eq. (2)
Additional controls:						
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Country-Year FE	No	No	Yes	Yes	Yes	Yes
R ²	0.07	0.61	0.63	0.63	0.63	0.63
Observations	13,114	13,114	13,114	13,114	13,114	13,114

Notes: This table presents estimates from regressions explaining the effect of the Enforcement Directive on firms' interest expenses. The estimates displayed in Columns I-IV replicate the first four columns in Table 5 but use firms' annual interest burden as dependent variable. Interest burden is calculated as firms total interest expenditures within a period over the average amount of long-term debt holdings during that period. Columns V and VI repeat the specifications from Columns III and IV, but add a dummy for young and private SME interacted with both the *Post* indicator and the term *Post* × PVal^{pre, high}. Young and private SME are defined in accordance to Section 5.1. Standard errors (in parentheses) are heteroscedasticity-consistent and clustered at the firm level. In both panels, *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

which measures the degree of dependence on external finance by relating firms' capital expenditures (*Capex*) to their cash flows (*CF*): $(Capex - CF)/CF$. Higher values imply that firms are less likely to cover their investments in fixed assets with internal funds, indicating a higher demand for external finance. This measure is a valuable addition to the analysis because it does not directly utilize information on firm age and size. For classifying firms according to the S&A index and the RZ-score, we consider the overall distribution of the respective scores during the three years before the country-specific Enforcement Directive adoption. Firms are considered financially constrained if they score above the industry-specific median value and vice versa. This way, we mitigate concerns regarding endogenous classification and inaccuracies of the two indices.

Panel B in Table 9 displays regression estimates explaining changes in long-term debt ratios of ex-ante financially constrained and unconstrained firms and firms with high or low dependence on external financing, as defined above. The results consistently indicate large positive effects on ex-ante financially constrained firms with valuable patent portfolios. The coefficients are positive and highly significant for young, private SMEs and firms classified as financially constrained or dependent on external financing according to their pre-treatment S&A index and RZ values, respectively. In contrast, for larger and unconstrained firms, the coefficients are positive but much smaller and mostly insignificant. Moreover, for firms with high RZ scores, the DID estimator is significant at the one percent level and about 1.6 times larger (2.489) compared to firms with low scores (1.509), for which the coefficient is statistically insignificant. Between these subgroups, there is no statis-

tical difference in the average ex-ante long-term debt-to-assets ratio of debt (high RZ-score: 13.7%, low RZ-score: 13.4%, t-value: 0.45). For robustness, we repeat this analysis using the number of amendments to domestic legislation as a treatment variable. Regressions are equivalent to Panel A of Table IA11 but consider only financially constrained firms and firms dependent on external debt financing. Results displayed in Panel C of Table IA11 confirm the above results. In sum, these results highlight that the Enforcement Directive enhances the debt capacity of patenting firms with limited access to financing.

5.2. Costs of debt as a potential mechanism

We examine the costs of obtaining debt as a potential channel through which the Enforcement Directive enhanced debt financing activities. As discussed in Section 2, enhanced patent enforcement mitigates the uncertainty associated with patents' legal scope and value. Since the price of a loan resembles the underlying risk associated with a borrower, lower uncertainty regarding patent enforcement should translate to lower costs of obtaining external debt financing.

To measure borrowing costs, we calculate firms' annual interest burden as the fraction of total interest expenses within a year over the average long-term debt held during the same period.²¹ We use this measure to estimate the effect of the Enforcement Directive on

²¹ We use this approach since our sample does not comprise individual loan-level information and, thus, interest rates. This measurement likely tends to

the interest burden of patenting firms. Regressions use a subsample of firms that increase their use of debt financing (i.e., comparing pre- and post-treatment averages in long-term debt ratios) such that a potential decline in the interest burden does not merely reflect a lower use of external financing.

Columns I-IV of Table 10 repeat the estimations from our baseline model and are defined as in Table 5 but use firms' annual interest burden ratio as the dependent variable. Across specifications, the coefficients on the *Post*-dummy are negative, economically meaningful, and statistically highly significant. The negative coefficient in Column I suggests a general decline in interest burden for patenting firms. The signs of the estimates on the firm-level control variables (i.e., capital structure determinants) are inverted compared to the baseline results, consistent with the inverse relation between the costs and use of debt. Importantly, the highly significant, negative DID estimator in Column II shows that the effect is more pronounced for firms with relatively high ex-ante patenting intensities. Comparing the DID estimator with the treatment coefficient (-1.269 and -0.896) suggests a disproportionately larger reduction in interest burden for this subgroup relative to patenting firms with lower portfolio measures by about a factor of 2.4. The result is robust to adding fixed effects and using both portfolio measures; see Columns III and IV, respectively. With an average pre-treatment interest burden of 13 pp, the point estimate in Column III suggests a disproportional reduction in interest burden of about 10% for the average firm with high-value patent portfolios.

Columns V and VI repeat the previous two specifications but add interactions of the main regressors with an indicator variable for firms that disproportionately benefited from the Enforcement Directive: young, private SMEs. These firms did not per se experience a disproportional decrease in borrowing costs on average, as indicated by the insignificant point estimate of the interactions of SME^{YP} with the *Post*-dummy. However, estimates on the triple interaction term ($Post \times PVa^{pre, high} \times SME^{YP}$) are negative and significant using both $PVa^{pre, high}$ specifications. This finding indicates that the directive leads to a disproportional decrease in the borrowing costs of these firms, conditional on owning relatively valuable patent portfolios before the change in the law. These results corroborate our previous findings on who benefits from stronger patent enforcement and suggest that the Enforcement Directive stimulated firms' use of debt by lowering the costs of obtaining external debt financing. Moreover, they emphasize the significant effect of the Enforcement Directive on young, private SMEs.

5.3. Cash flow- and asset-backed lending: evidence from patent pledges

This section investigates the role of patent pledges in the context of the Enforcement Directive, which resembles a direct form of asset-based lending in our setting. To study this, we augment our dataset with previously undisclosed data on patent pledges for French, Dutch, and Swedish firms. In these countries, reporting patent-related security interests to the responsible IP authorities is mandatory.²² We web-scrape data on patent collateral pledges from the official data warehouses of the three respective IP offices. This data includes patent application numbers that allow us to link pledge information directly to our sample. France, the Netherlands, and Sweden constitute a well-suited subsample because these countries 1) constitute about one-quarter of observations from our sample, 2) transposed the Enforcement Directive in different

years, and 3) made significant amendments to their domestic legislation (see Section 4.2).

To illustrate the validity of the data, Panel A of Table 11 displays the average year-over-year change in long-term debt ratios for the subsample of patent pledging firms. It spans a firm-specific, symmetric time window of four years around a patent pledge. In this time window, the average growth rate is positive and statistically significant only during the year of the pledge. As an alternative verification approach, we calculate the mean values of the patent portfolio measures from Equations (1) and (2) both before and after firms' patent pledges. For pledging firms, patent portfolio values almost double comparing pre (3,346) to post (6,546) pledge averages. This observation is consistent with the 'positive feedback effect' (Mann 2018, p. 21) of patent pledges on subsequent patenting activities.

Next, we analyze the effects of patent pledges for debt financing and their role in the Enforcement Directive context. Panel B of Table 11 displays estimation results using different regression specifications. First, in Column I, we estimate the effect of a patent pledge on firms' long-term debt ratios, controlling for capital structure determinants and firm- and country-year fixed effects. The estimation uses the sample of pledging firms. The dummy variable *Pledge* is equal to one for all subsequent years after a patent pledge, capturing the effect of the pledge on firms' use of debt. The corresponding coefficient is positive and significant at the one percent level. Its magnitude suggests an economically meaningful increase in debt ratios by 4 pp, equal to about 30% of their average pre-pledge long-term debt ratios.

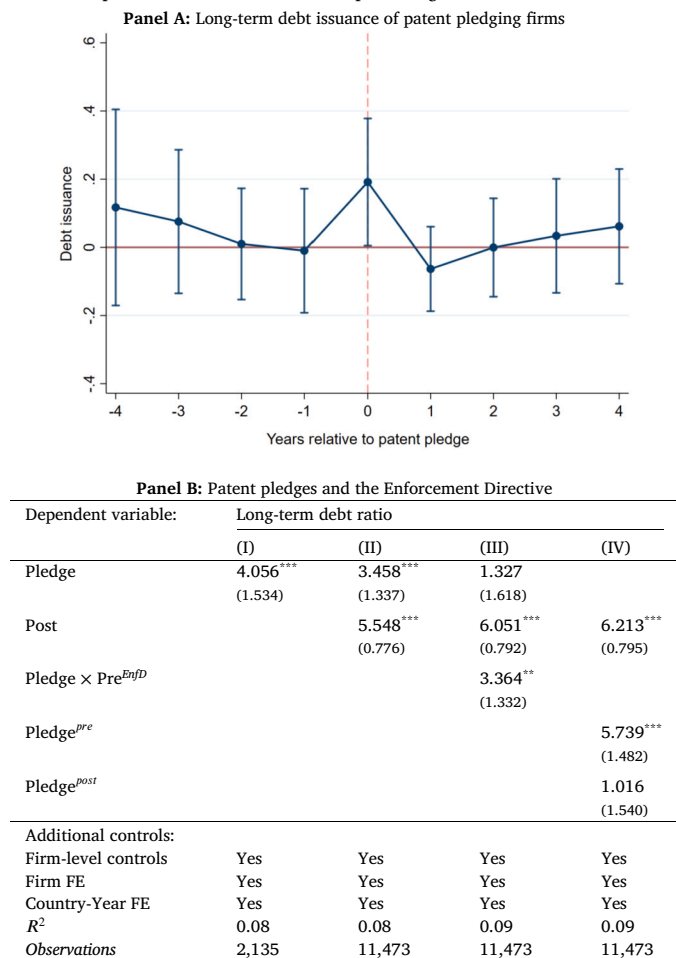
Further, we find that the positive effect of patent enforcement on the debt capacity of firms is complementary to the use of patents as loan collateral. In Column II, we reestimate the previous specification for the full subsample of French, Dutch, and Swedish firms and add the *Post* dummy, as defined in the main analyses. The coefficients for both dummies are positive and highly significant. Controlling for patent pledges thus does not attenuate the positive effect of the Enforcement Directive on the long-term debt ratios of patenting firms. If anything, the impact of the legal change is more pronounced (5.548) than the effect of the patent pledge itself (3.458).

Moreover, we find a larger effect of pledges on firms' debt ratios for pledge events before the Enforcement Directive than after its adoption. Column III repeats the estimation of Column II but adds an interaction term of the *Pledge* indicator with a dummy variable equal to one for all country-specific years in which the Directive was not transposed (Pre^{EnfD}). The coefficient on this interaction term is positive and significant, whereas the coefficient of the base term (i.e., *Pledge*) becomes much smaller and insignificant. Similarly, in Column IV, we split the *Pledge*-dummy into two separate indicators that equal one for all years after a patent pledge, distinguishing pledge dates before ($Pledge^{pre}$) and after ($Pledge^{post}$) the implementation of the Enforcement Directive. The estimated coefficients of these dummies are positive, but only the one for $Pledge^{pre}$ is large and statistically significant, confirming Column III's results. Consistent with previous estimates, the effect of the Enforcement Directive itself remains positive and highly significant. These findings support the interpretation that the Enforcement Directive captures a positive shift in the ability of firms to attract debt financing. On top of this, they show that the amendments enhance firms' debt financing even when patents are not explicitly used as collateral. In other words, based on our subsample analysis, the positive effect of the Enforcement Directive cannot be exclusively attributed to asset-based lending but mostly likely captures an increased use of cash flow-based lending. Enhanced patent enforcement may have updated lenders' expectations regarding the future cash flows associated with patent portfolios. This aspect is important, especially for innovation-intensive firms, because of the low liquidation recovery rates of intangibles relative to tangible assets (Kermani and Ma 2023). Enhanced enforcement likely raises the (going-concern) value of patenting firms, which is a key dimension for creditors to provide debt (see Kermani and Ma 2022). Consistently, evidence on cash flow- versus asset-backed lending shows

overestimate interest payments (and thus biases our results downwards) because we consider all financial charges reported in a given year.

²² In many patenting-intensive economies, such as the US, Japan, or Germany, consistent registration is not warranted (e.g., Graham et al. 2018; Picht 2018). In France, reporting is not mandatory, but legislation strongly incentivizes timely registration. Patent pledge registration is also compulsory in other European countries, irrelevant to our study, i.e., Belgium (collateral data is only available as of 2015), Luxembourg, and Norway.

Table 11
The use of patents as loan collateral and patent right enforcement.



Notes: In Panel A plots the average debt issuance of patent pledging firms measured by the year-over-year growth in long-term debt: $(ltdb_t - ltdb_{t-1})/ltdb_{t-1}$, with $ltdb$ denoting firms debt holdings with a maturity of more than one year. Unlike the main sample, we restrict the sample to firms in France, the Netherlands, and Sweden, i.e., countries for which we have patent pledge data. The graph displays a firm-specific symmetric time window of four years around respective pledge events. Whiskers span the 95 percent confidence intervals. Panel B displays estimates on regressions explaining the simultaneous effects of patent pledges and the Enforcement Directive on long-term debt ratios. All regressions repeat the baseline specification from Equation (3) but use a set of different treatment variables that indicate the timing of both patent pledges and the implementation of the Enforcement Directive, as well as their interactions. In Column I, we use the subsample of patent pledging firms in France, the Netherlands, and Sweden. Columns II-IV use the full set of patenting firms within these countries. $Post^{pledge}$ is a dummy variable equal to one for all years after the first patent pledge of a firm. $Post$ indicates the adoption of the Enforcement Directive, just like in all previous estimations. The interaction of $Post^{pledge}$ and Pre^{EnfD} indicate all years after the patent pledge but before the Enforcement Directive was implemented (i.e., Pre^{EnfD}). $Pledge^{before}$ and $Pledge^{after}$ are dummy variables equal to one for all years after a patent pledge, and differentiates whether this pledge was constituted either before or after the Enforcement Directive was transposed into domestic law, respectively.

that firms increasingly secure loans with cash flows arising from their assets instead of directly using them as loan collateral (Lian and Ma 2021; Ivashina et al. 2022).

6. Conclusion

Agency costs affect debt financing, especially for innovation-intensive firms. However, these firms may use their intellectual prop-

erty to access debt financing and soften financial constraints. Our study investigates the role of the legal framework on innovative firms' debt financing. We exploit the implementation of the 2004 EU Enforcement Directive across EU member states as an exogenous source of variation in patent right enforcement for a large representative sample of patenting firms. We find that enhanced enforcement causally increases the use of debt financing of patenting firms. To identify this effect, we utilize variation across firms' patent portfolio characteristics before the change in law. We draw on specific features of the European patent fee schedule to measure several dimensions of patent portfolios on the firm level, repeatedly over time, and for virtually all patenting firms. Estimates suggest an additional 20% increase in long-term debt ratios for more patenting-intensive firms. This effect pertains to long-term debt but not to short-term debt, highlighting the main mechanism of the Enforcement Directive, which is to reduce the risk associated with patents.

Further analyses provide new evidence on how the legal framework shapes the financing activities of innovative firms. As such, the main results are most substantial for firms in countries with more adjustments to the legal system and for firms active in more competitive industries. As a central implication, relatively young, private SMEs, i.e., firms with initially limited access to financing, disproportionately increase their use of debt. Stronger and more harmonized enforcement helps these firms to raise debt by significantly lowering the costs of obtaining external debt financing. Moreover, we find that the Enforcement Directive helped innovative firms to exploit their patent portfolios for financing purposes, mostly by fostering cash flow-based lending, suggesting that enhanced patent enforcement promotes debt financing beyond the collateral value.

In sum, these results disclose comprehensive insights into the potential of IP assets to support debt financing activities using a previously unexplored context. They highlight the decisive role of the legal environment as a determinant of these effects. Moreover, our findings emphasize the benefits of improvements in the legal framework towards a more integrated system, addressing a central issue in IP policy, i.e., the high fragmentation in the global IP system. As such, strengthened IP enforcement law promotes the role of intellectual property, such as patents, for financing purposes.

Our results have significant managerial and governmental implications, especially considering the increasing importance of intangible assets for firm value and external financing (see Falato et al. 2022). From a managerial perspective, our findings suggest that firms should consider IP assets as a means to attract external financing. From a governmental perspective, our results show that a harmonized, reliable enforcement system supports respective financing activities for IP right owners. This strategy is promising, as it supports external financing activities of particularly vulnerable market participants, such as small and previously financially constrained, innovation-intensive firms.

CRedit authorship contribution statement

Andrej Gill: Methodology, Investigation, Conceptualization, Project administration, Supervision, Validation. **David Heller:** Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation.

Data availability

Data will be made available on request.

Appendix. Supplementary material

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.jbankfin.2024.107169>.

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