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**Working Paper**

767/2025  
September 2025

## **Financing Innovation: The Role of Patent Examination**

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**Economic  
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Research Council**

# Financing Innovation: The Role of Patent Examination\*

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September 2025

## Abstract

We examine how the design of the patent system shapes firms' access to finance. We exploit a UK reform that introduced substantive examination into the patent application process, improving the quality of information available to investors about the value of firms' innovation. Using a newly compiled dataset of officially listed corporations, we find that firms with examined patents increased their borrowing, reflecting improved access to capital markets, which translated into firm growth. Our results highlight how patent examination can function as a screening mechanism that reduces information asymmetry, strengthens the signalling value of patents, and mitigates financial barriers to innovation.

Keywords: firm finance, debt, innovation, patents, patent examination, signalling.

JEL Classification: G32, N23, N43, O16, O31, O34.

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\* We thank audiences at the UKRI Analysts' Learning Series (June 2021), the European Historical Economics Society (Groningen, June 2022), the World Economic History Congress (Paris, July 2022, and Lund, July 2025), Queen's University Belfast (September 2022), Stellenbosch University (March 2024), the European Policy for Intellectual Property Association (Pisa, September 2024), Heriot-Watt University (January 2025), the Economic History Society (Glasgow, April 2025), and the Association of Business Historians (Belfast, June 2025) for feedback on our research-in-progress. We benefited from comments on earlier drafts from Abe de Jong, Peter Koudijs, Tom Nicholas, and John Turner. We thank Thomas Boys, Paudie McKee, Andrew Richie, Kyle Richmond, Holly Shannon, and Hemant Tiwari for excellent research assistance. We acknowledge funding from the Economic History Society, the Royal Economic Society, and the Government of Ireland's North-South Research Programme.

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## 1. Introduction

Innovation is a key driver of economic growth, yet innovative firms face significant challenges in securing adequate investment (Janeway, 2012; Kerr and Nanda, 2015; Nanda and Rhodes-Kropf, 2016). This stems from the intangible and uncertain nature of new inventions, which makes them inherently difficult for investors to evaluate (Hall, 2002). Their long and unpredictable return horizons clash with investors' preferences for short-term and certain gains (Kay, 2012; Besley et al., 2013; Davies et al., 2014). Information asymmetries between innovators and investors further exacerbate these problems, giving rise to risks of adverse selection and moral hazard (Hall, 2009b; Hall and Helmers, 2024). The combination of fundamental uncertainty and risks rooted in information asymmetry can force innovative firms to rely on alternative financing mechanisms (Nicholas, 2011a; Bakker, 2013) or prevents them from securing adequate funding to support their development and growth (Hall and Lerner, 2010).

Patents offer a potential solution to these financing problems. Traditionally, the private value of patent rights has been understood to derive purely from their exclusionary function. Patents are modelled as intellectual property rights that raise entry barriers by increasing imitation costs, granting entrepreneurs time to recoup their initial investment, thereby enhancing the attractiveness of patenting firms to investors (Arrow, 1962; Mansfield et al., 1981; Edquist and Johnson, 1997; Scotchmer, 2004). More recent scholarship has examined an additional channel through which patents can derive value: their potential to reduce information asymmetries between firms and prospective investors as they are positively correlated with knowledge capital and can also act as collateral (Long, 2002; Useche, 2014; Saidi and Žaldokas, 2017; Mann, 2018; Hochberg et al., 2018; Suh, 2023).<sup>1</sup> By providing a credible “signal” of a firm’s innovation performance and returns potential, the patent system can be used to mitigate the risks and uncertainties of investing in innovative firms (Hall, 2009b; Harhoff, 2009). Crucially, however, the strength of this signal depends on the extent to which granted patents serve as an accurate and reliable indicator of the value of the underlying invention. Thus, the design of the patent system is critical, not just for its ability to exclude imitators through the legal system, but also as a formal institution that provides a government-backed quality control mechanism.

Empirically evaluating the efficacy of patents as signals of innovative value necessitates finding an appropriate quasi-natural experimental setting. But exploitable policy changes and

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<sup>1</sup> Patents may also reduce information asymmetries between firms and their customers (Ertugrul et al., 2024).

other econometrically useful shocks to national innovation systems are incredibly rare events. Our paper is the first to exploit one such rare event: the introduction of screening to the UK's patent application process. The 1902 Patents Act instituted, for the first time, a substantive examination step into the British patent system, taking effect from 1 January 1905. Under the new regime, trained patent examiners with a scientific education conducted prior art searches on all new applications by reviewing the past 50 years of published British patent specifications for any inventions making similar claims. Applicants were provided with their examiners' prior art search reports, and then given the opportunity to revise their patent claims or withdraw their application altogether.

We treat this policy change as a quasi-natural experiment, employing difference-in-differences models to investigate whether the introduction of examination improved access to finance for patenting firms by enhancing the signalling credibility and observability of their patented invention, through improved screening (Connelly, 2011). To do so, we construct a new dataset comprising all patenting firms officially listed on the London Stock Exchange. Our study window spans the period 1899–1913, capturing six years before and nine years after the 1905 policy change. This dataset itself represents an important contribution: no financial database is available for this period, so we hand-collected and digitised firm balance sheets, profit and loss accounts and corporate governance information from historical archives – the same approach as Braggion and Moore's (2011) study of dividend policy in this historical period. We use our unique dataset to assess whether the capital structure, the source of debt, and the size of patenting firms changed in response to this reform, relative to a control group of non-patenting firms.

We find that the introduction of patent examination significantly influenced the borrowing behaviour of patenting firms. Specifically, firms patenting after 1905 exhibited a marked and statistically significant increase in their debt-to-assets ratios, suggesting that patent examination improved access to credit for these innovative firms. Notably, this effect was driven by increased access to capital market debt rather than bank lending or trade credit. Firms with examined patents borrowed substantially more through bond markets, a pattern consistent with pecking order theory, whereby firms prefer debt over equity when external finance is required (Myers and Majluf, 1984). We find that patent examination is associated with growth in the size of innovative firms, rather than just a rebalancing of capital structure. This suggests that the patent system's interaction with capital markets can play an important role in stimulating innovation-led growth. Our results are robust across a range of sensitivity checks and alternative specifications.

Our findings contribute to the growing literature demonstrating the role of patents in facilitating access to finance (e.g., Baum and Silverman, 2004; Haeussler et al., 2009; Greenberg, 2013; Hsu and Ziedonis, 2013; Conti et al., 2013; Haeussler et al., 2014; Hochberg et al., 2018; Hall, 2019; Farre-Mensa et al. 2020; Hegde et al., 2022). Much of this existing work focuses on start-ups and venture capital financing, with less attention given to more mature, publicly listed corporations. The literature has established that innovative firms are often credit constrained, and consequently more dependent on equity than debt financing (e.g., Brown et al., 2009; Brown et al. 2013). However, several recent studies have shown how debt, particularly from banks, is becoming a more viable option for financing innovation due to the collateral function patents can serve (Robb and Robinson, 2012; Kerr and Nanda, 2015; Bracht and Czarnitzki, 2022; Ayerbe et al., 2023; Ciaramella et al., 2024). By examining capital market debt across a broader spectrum of the corporate lifecycle – from recently-listed firms to mature corporations – our study adds a novel dimension to this evolving literature.

Saidi and Žaldokas (2017) show that the signalling value of a patent can substitute for a relationship-based lender’s “soft” information, increasing access to capital markets. Mann (2018) and Hochberg et al. (2018) employ records from the USPTO on the use of patents as collateral to identify the role patents play in enhancing access to finance. Suh (2023) finds that legal rulings that secured firms’ rights over patents lead to increased use of patents as collateral and higher debt-to-assets ratios. And Gill and Heller (2024) show how a 2004 change in EU law, which strengthened patent rights, led to significant increases in debt financing by patenting firms, along with lower interest rates. Our results are consistent with these findings, showing that patent examination unlocked debt financing, and facilitated greater access to capital markets rather than bank debt or trade credit. We think that our findings contain potentially useful lessons for policymakers wishing to stimulate innovation, especially because the type of finance that firms obtain has been linked to growth and innovation at an aggregate level.<sup>2</sup>

Our paper advances our understanding of the signalling value of patents, in contrast to the value derived from patents’ exclusionary function. Disentangling these two dimensions is empirically challenging, and the existing literature offers mixed evidence on whether patents act as effective signals (Hall, 2019). Some studies find that patents are important, independent of any signal they may send about innovation quality (Hottenrott et al., 2017; Hochberg et al., 2018). Others suggest that it is the intrinsic quality of the underlying innovation that drives access to finance, rather than the simple existence of an exclusionary patent right (Haeussler et

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<sup>2</sup> Hsu et al. (2014) find that industries more reliant on external finance have higher innovation levels, and Geelen et al. (2022) argue that debt fosters rather than hampers innovation and growth on aggregate.

al., 2014; Farre-Mensa et al., 2020).<sup>3</sup> Schankerman and Schuett (2022) model the patenting process theoretically as a signalling game, but inventors there are not credit constrained and financial frictions do not feature. In Schuett's (2012) theoretical model, where financial markets are assumed to be imperfect, the signal quality is determined by the patent office's examination intensity, and the combination of higher intensity and lower fees is modelled to improve access to finance. Our empirical findings are consistent with the view that patents can signal the underlying novelty of inventions, and that the signal quality can influence innovative firms' access to finance.

Our findings also contribute to the wider literature on patent quality, the design of patent institutions, and the optimal level of patent examination (Caillaud and Duchêne, 2011; Atal and Bar, 2014; Castaldi et al., 2024; Liu, 2024). Patent quality has long been a subject of economic inquiry due to the potential social costs associated with low-quality patents.<sup>4</sup> Patent examination standards represent one policy lever that can be manipulated to change patent quality. Sampat (2010) finds that applicants routinely fail to cite relevant prior art. Langinier and Marcoul (2016) model patent examination as a strategic game between applicants and examiners, arguing that improving patent quality depends on aligning incentives to promote full disclosure of the prior art. Allison and Hunter (2006) highlight how a US patent quality improvement initiative, which increased examiner-added prior art references, led applicants to adapt by citing such references themselves. Together, these studies underscore the dynamic interaction between patent office procedures and applicant behaviour. Our findings contribute by providing evidence that formal examination can improve patent quality, and that this has the knock-on effect of enhancing the informational value of patents in financial markets.

Finally, our findings add to the literature that examines patenting and innovation incentives from a long-run historical perspective (Lerner, 2002; Moser, 2013; Kelly et al. 2021; Billington et al., 2024). Recent contributions to this literature include: Nanda and Nicholas (2014) on the impact of bank failures during the Great Depression on the level and quality of innovation by patenting firms; Lehmann-Hasemeyer and Streb (2016) on the IPO performance of patenting firms in Germany for the same historical period as our own; Donges et al. (2023) on the impact of the introduction of inclusive institutions due to France's 1789 occupation of Germany on patenting activity; and Babina et al. (2023) on the long-run impact of the Great

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<sup>3</sup> R&D expenditure has been found as another way in which firms are able to signal innovation potential (see Hepfer et al., 2025).

<sup>4</sup> It is useful to distinguish patent quality from the quality of information about patents. The former is concerned with the private and social value of patents, whereas the latter is one means of determining the former. Patent quality is measured in different ways in different works, including using renewal data and forward citations. Lanjouw and Schankerman (2004) and Shu et al. (2022) link patent quality with the stock market value of firms.

Depression on the patenting behaviour of firms and individuals. By focusing on a key institutional reform in UK patent history, our study adds to this literature by demonstrating how a change in the design of patent institutions can have consequences for innovation finance.

Our paper proceeds as follows: Section 2 explains the institutional background to the 1905 patent system reforms and, drawing on economic and financial theory, develops hypotheses on how they shaped firms' financing decisions. Section 3 describes our data and explains trends in patenting practices over our sample period. Section 4 discusses our econometric methodology and presents our core and additional empirical results. Finally, Section 5 concludes.

## **2. Background and hypotheses**

The purpose of screening patent applications is to prevent the patenting of low social value inventions, or inventions that would raise social costs. Broadly, patent authorities have two screening mechanisms at their disposal: (1) they can manipulate the costs of obtaining protection using application fees; and (2) they can assess the social value of applications through patent examination (Encaoua et al., 2006; de Rassenfosse and van Pottelsberghe de la Potterie, 2013; Kou et al., 2013). Charging high patent fees is designed to encourage only high-quality inventors to self-select into using the patent system (Burhop, 2010), but will also have the effect of excluding access to patent protection to credit-constrained inventors (Macleod et al., 2003; MacLeod and Nuvolari, 2016). In contrast, using patent examination to ensure inventions meet agreed standards of novelty and utility makes patents open to all, irrespective of ability to pay – what Acemoglu and Robinson (2012) call an inclusive economic institution. By raising the average quality of granted patents, patent examination can also help strengthen the signal to investors of the potential yield associated with patenting firms' R&D portfolios (Hall, 2019).

Patent systems around the world have very different levels of in-built examination (de Saint-Georges and van Pottelsberghe de la Potterie, 2013; Picard and van Pottelsberghe de la Potterie, 2013; Harhoff, 2016). Most employ legal professionals to make sure the minimum legal requirements of the application are met – a so-called “formalities examination”. Many go further and employ scientifically trained examiners to classify the invention and check it against the existing literature – a so-called “prior art search” – and to then to judge whether the invention meets patentability requirements surrounding novelty, inventive step (or non-obviousness) and industrial applicability (utility). This more sophisticated, lengthy and costly

process is known as “substantive examination”.<sup>5</sup> But some systems, known as “patent registration systems”, do not have any such processes; a patent is issued almost as soon as the appropriate fees are paid and documents filed, and there is no initial determination of validity; all quality control is essentially left to *ex post* private enforcement through the courts.

The historical development of Britain’s patent system reflects the transition from one of registration with minimal government involvement in the screening of patent applications, to one with a substantive examination step conducted by experts employed by the Patent Office. The Patents, Designs, and Trade Marks Act of 1883 first moved the system from one of pure registration towards having a light-touch formalities examination of patent descriptions (Nicholas, 2011b).<sup>6</sup> But the 1883 Act also significantly decreased patent fees.<sup>7</sup> While this made the patent system a more inclusive economic institution, it meant high-quality patent applicants were much less likely to sort into, and low-quality applicants out of, the patent system. Following Spence (1973), the market’s design can be said to have gone from generating a separating equilibrium to a new pooling equilibrium. The absence of any meaningful screening element between 1883 and 1905 arguably produced a patent system of low social value and high social cost. We also think that the pre-1905 patent system did little to help alleviate information asymmetries between innovative firms and investors. Essentially, unexamined patents were “cheap talk”, and the patent system functioned like a “market for lemons” (following Akerlof, 1970; Leland and Pyle, 1977).

Contemporaries raised concerns about the social costs of the post-1883 patent system. Principally, they complained of the wasteful allocation of resources directed toward the patenting of obvious inventions, or inventions already patented before, coupled with a greater risk of litigious rent-seeking behaviour. In one example, a patented method of insurance investment was strongly questioned in *The Financial Times* and investors were advised to steer clear.<sup>8</sup> Evidence submitted before a 1901 Parliamentary Committee, convened to investigate the utility of adopting a stronger form of patent examination, demonstrated that up to 42 per cent of all patents granted between 1898 and 1900 were for inventions that were neither new, novel, nor non-obvious (House of Commons, 1901). The consequence of the committee’s work

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<sup>5</sup> Even within these systems, examiner experience and workloads may limit the accuracy of examination (Lemley and Sampat, 2012; Kim and Oh, 2017; Shu et al., 2022).

<sup>6</sup> Patent Office examiners were trained to check for consistency between an application’s provisional specification outlining the nature of the invention, and the later complete specification which provided the technical details. When inconsistencies were identified, the applicant was required to redraft their complete specification.

<sup>7</sup> The 1883 reform reduced filing fees by 84%; patenting increased 2.5-fold (Nicholas, 2011b).

<sup>8</sup> *The Financial Times* (22 August 1899, p. 2) questioned how a method of investment could be patentable. It described the company involved as a ‘pig-in-a-poke’, and the concept as ‘bunkum not deserving the least consideration from investors’.

was the adoption of a more substantive examination step with the passing of the 1902 Patents Act, which came into effect in January 1905.<sup>9</sup> The Act was described as a ‘revolution of the patent law’ by the then Comptroller-General of Patents, the Patent Office’s chief executive.<sup>10</sup> We hypothesise that this 1905 reform meant obtaining a patent became a more reliable signal of innovation quality. We think this government intervention helped to establish a new separating equilibrium where firms with low-quality inventions self-selected out – or were actively screened out – of using the patent system.

[INSERT FIGURE 1 HERE]

The new patent examination process constituted a team of trained patent examiners screening patent applications against the prior art (see Figure 1). Examiners were skilled and the hiring process was highly selective; prospective examiners were evaluated on their proficiency in several technical areas.<sup>11</sup> The examiner’s role was to identify any patents from the previous 50 years of British patent grants that may have pre-empted or “anticipated” the invention for which protection was being sought in terms of its technical features (known as “claims”).<sup>12</sup> The examiner communicated the results of their search to the applicant, providing them, where necessary, with a list of all anticipating patent specifications. The applicant was then given the opportunity to amend their specifications to more precisely define the novelty of their claims in light of the search report, or withdraw their application altogether. If the applicant refused to revise their application, the examiner’s list of anticipating references would be appended to the patent specification and labelled as “forced references”, making the patent’s questionable novelty claims public knowledge. A small additional examination fee was levied to encourage low-quality applicants to withdraw their application during this process.<sup>13</sup> Patent examiners had no authority to refuse the grant of a patent on grounds of novelty; an anticipated

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<sup>9</sup> This act did not substantially change patent rights in other ways; the term of a patent remained 14 years.

<sup>10</sup> ‘Working of Patents Act 1902 (1905)’, Board of Trade: Patent Office and Industrial Property and Copyright Department and predecessors. BT 209/4, National Archives, London.

<sup>11</sup> Patent Office examination records indicate that patent examiners had to score at least 1520 points out of a total of 2600 across the following subject areas: ‘English Composition’, ‘Geometry’, ‘Mechanics and Mechanism’, ‘Chemistry’, ‘Electricity and Magnetism’, ‘General Physics’, ‘French’, and ‘German’. In one round of recruitment, dated 17 February 1903, the Patent Office hired 12 out of 71 candidates following the exam. Assistant Examiner, Patent Office (17 February 1903), Civil Service Commission: Examination, Tables of Marks and Results. CSC 10/2193, National Archives, London.

<sup>12</sup> This differed from other countries’ patent examination systems whose examiners engaged in a broader novelty search. Contemporaries were aware of the difference (see commentary in *The Times*, 25 December 1908).

<sup>13</sup> The choice to add an additional £1 fee to be paid upon receipt of the examiner’s report, but prior to paying the fee for sealing their patent, was to encourage applicant’s seeking ‘bad’ patents to simply abandon them. £1 in 1905 is equivalent to about £135 in 2025 prices, and £800 relative to GDP per capita in 2025 (<https://www.measuringworth.com/>).

patent could still be obtained, but now the public had access to the requisite information to evaluate a patent's novelty at no cost to themselves.<sup>14</sup>

Consequently, there are two channels through which patent examination may have acted to enhance signalling and reduce information asymmetries between inventors and investors. First, the examination and grant of a non-anticipated patent would have directly helped investors identify the most innovative firms. Second, the addition of references to the specifications of patents deemed not novel by patent examiners would have either discouraged inventors from pursuing low-quality applications by abandoning them, or discouraged investors from backing firms that held such patents. Both channels serve to improve the average quality of patents granted under the new examination regime and strengthen the direct value-signalling characteristic of a patent.<sup>15</sup> We hypothesise that the introduction of patent examination therefore improved the quality of the patent pool in Britain after 1905. This aligns with recent studies, which argue that the quality of patents granted is greater in patent systems that employ more rigorous patent examination (de Rassenfosse et al., 2021).

Contemporary observers of the 1905 legal change were well aware that patents had the potential to signal the value of underlying innovation to market participants, and that patent examination could strengthen this signal through a formal screening process.<sup>16</sup> In the absence of patent examination, some firms took it upon themselves to privately employ patent agents and other experts to assess the novelty and utility of their patents. These assessments were sometimes included in company prospectuses as a private mechanism to demonstrate the quality of their innovations to potential investors.<sup>17</sup> Commentators at the time argued that newly government-examined patents not only better reflected a firm's innovation capabilities and the prospective novelty of its ideas, but also the potential commercial success of the

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<sup>14</sup> Patent law was further amended with the Patents and Designs Act 1907, which added provisions for administrative enforcement of the working clause for foreign patentees. But these provisions proved unenforceable. No change was made to the fee schedule or the examination regime; the 1907 act served mostly to consolidate various old IP laws (Adams, 2007).

<sup>15</sup> The Comptroller-General opined that prior art search had 'materially enhanced the value of patents granted in the United Kingdom,' and that 'every effort is made to eliminate irrelevant matter from the specifications, to make the claims clear and succinct, to define the state of the art, and to insert references to any patents which seem to require special notice in the interest of the public' (House of Commons, 1910).

<sup>16</sup> Witnesses to the 1901 Parliamentary Committee were concerned that the public would perceive the Patent Office's examination of patents as a guarantee of novelty, especially in instances where the examiner did not find anything. Some contemporaries were concerned that the public might interpret this signal too optimistically. See opposition to the new legislation in *The Economist* (12 April 1902).

<sup>17</sup> See, e.g., the prospectus for Nernst Electric Light, Limited, where experts are quoted as claiming the company's electric lighting patent is for an invention that is 'fundamentally different from anything that preceded it' (*The Times*, 27 February 1899). See Appendix B for more examples and discussion.

technology.<sup>18</sup> The introduction of a formal screening process, which raised the novelty and non-obviousness requirements, signalled that granted patents had a higher likelihood of generating future revenue streams.

We hypothesise that the introduction of patent examination should have improved access to finance for patenting firms, by reducing information asymmetries between firms and investors, and reducing the risks associated with investing in innovative firms. Pecking order theory predicts that firms will prioritise debt financing over equity, where possible, as it is less costly because it does not require sacrificing ownership and control rights (Myers and Majluf, 1984; Harhoff, 2009).<sup>19</sup> Studies of modern patent systems show that firms use their patent assets as a form of collateral to raise debt financing (e.g., Robb and Robinson, 2012; Fischer and Ringler, 2014; Kerr and Nanda, 2015; de Rassenfosse and Fischer, 2016; Mann, 2018; Bracht and Czarnitzki, 2022; Ayerbe et al., 2023; Ciaramella et al., 2024).<sup>20</sup> The presence of a floating charge over all company assets that secured bondholders during our historical sample period meant that a firm's entire patent portfolio *de facto* functioned as collateral when it raised debt (Coyle and Turner, 2013). In addition, many of our patenting firms specifically listed patents as an asset on their balance sheets, suggesting they functioned as valuable collateral securing bondholders.<sup>21</sup> Evidence from contemporary press confirms that patents were regarded as key company assets in our period, both before and after the introduction of examination. Their monetary value was frequently cited in the context of attracting investors, as was their use as security for bondholders (see Appendix B). We hypothesise that examined patents were worth more in terms of their expected value than unexamined patents, enabling patenting firms to raise more debt relative to non-patenting firms or firms with unexamined patents.

Our argument focuses on the signal of an examined patent's innovative value. While the design of the rest of the patent system, including the courts, remained unchanged, we do not deny the possibility that the introduction of prior art search examination also affected the exclusionary value of patents. Viewing patents as probabilistic property rights following

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<sup>18</sup> A legislative roundup of 1902 published in *The Times* (15 January 1903) argued that patent examination will increase inventors' confidence in being the "true and first inventor," and enhance the saleable value of the patent', but cautioned that examination is 'nevertheless, not in any way to guarantee the legal validity of the patent'.

<sup>19</sup> Trade-off theory also predicts a preference for debt over equity in the presence of a tax shield (Modigliani and Miller, 1963; Kraus and Litzenberger, 1973). However, there was no corporate tax system in our period of enquiry (Braggion and Moore, 2011).

<sup>20</sup> Patents can also be used to motivate raising equity; Lehmann-Hasemeyer and Streb (2016) find that German firms used their patent portfolios to signal their value during IPOs in the period 1892–1913.

<sup>21</sup> Firm balance sheets generally do not give a specific pound value for patents because they are typically included in combination with other intangible assets. We therefore cannot analyse this separately.

Lemley and Shapiro (2005), we can hypothesise that examination increased the probability that a patented invention is novel, and therefore decreased the probability that the patent will be annulled in the courts following a challenge by competitors.<sup>22</sup> Essentially, however, any change in patent value viewed through this more traditional exclusionary function “lens” also hinges on the examination process’s ability to screen out anticipated patent applications and signal innovation quality more effectively.

### **3. Data and descriptive statistics**

To examine the effect of patent examination on the ability of patenting firms to raise external finance, we focus our analysis on stock exchange-listed companies, as this enables the collection of reliable data on firm finances, and these firms had access to both banks and capital markets. An additional benefit of this approach is that literature to date has predominantly focused on the relationship between innovation and finance of unlisted start-up companies. To this end, we have collected data for all patenting firms listed on the London Stock Exchange during the period 1899–1913, along with a control group of non-patenting firms.

To identify patenting firms, we first collected patent data from the European Patent Office’s (EPO) PATSTAT Biblio database (Autumn 2016 version).<sup>23</sup> PATSTAT is a comprehensive database of all patents granted in EPO member states, in addition to Japan and the USA. The historical coverage of PATSTAT is incomplete, but British patent data are comprehensive from the late 1890s onwards (Billington and Hanna, 2021). We begin our analysis in 1899 to ensure that we have all patents granted in Britain, and a large window of data before examination was introduced in 1905. 1913 is a natural endpoint to our analysis due to the outbreak of World War I. PATSTAT includes patentee name(s), filing (application) year, grant year, patent title, abstract, complete specification, and number of forward citations.

We then manually matched our patent data with companies listed on the London Stock Exchange, by collecting data from Investor’s Monthly Manual (IMM) and Stock Exchange Daily Official Lists (SEDOL).<sup>24</sup> This produced an initial list of 150 patenting companies, which reflects the population of officially listed patenting companies in Britain in the period 1899–1913. All our patenting companies are classified as either ‘Commercial, Industrial’ or ‘Iron,

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<sup>22</sup> No digitised database of patent infringement cases is available for this historical period. A new database would need to be constructed from Patent Office records to test this hypothesis.

<sup>23</sup> Appendix Table A1 counts total patent applications filed during the first nine years of the examined system.

<sup>24</sup> IMM is available digitally via the International Center for Finance at the Yale School of Management; printed copies of SEDOL are held at the Guildhall Library, London.

Coal, Steel’ in SEDOL. Our control group initially constitutes 200 non-patenting firms drawn from the same two SEDOL categories using a random number generator.<sup>25</sup>

Next, we hand-collected annual balance sheet records for each firm. Unfortunately, balance sheets have not survived at the Guildhall Library in London for all companies in our dataset. Our final dataset therefore constitutes 132 patenting companies, which represents all officially listed British patenting companies that were in existence part, or all, of the time between 1899 and 1913 for which data are available, and 163 non-patenting control companies.<sup>26</sup> This gives us 2,509 firm-year observations.

### *3.1 Patent data*

Figure 2 shows total patenting activity in Britain before and after the 1902 Patents Act. The figure plots the ratio of patents granted (‘sealed’) each year against yearly total applications, yearly complete specification filings, and yearly provisional specification filings. Comparing the number of complete specifications with the number of patents sealed before and after the reform gives us an indication of whether the new examination system was encouraging low-quality patents to be abandoned. Prior to 1905, the share of patent grants maps very closely onto the share of complete specifications submitted. However, after 1905 there is a clear divergence between the two series. This suggests that a group of patent applicants was now opting to abandon their applications after the examination step, and in so doing increasing the overall quality of the remaining patent pool. Additionally, after 1905, the ratio of sealed patents to provisional specifications rises, which suggests a reduction in the filing of applications for non-novel inventions, further indicating an increase in patent pool quality.

[INSERT FIGURE 2 HERE]

[INSERT TABLE 1 HERE]

Statistics on the outcome of patent examination for the population of British patents are in Table 1. ‘Prior art search’ illustrates the level of anticipation patent examiners found in complete patent specifications each year. Only one-third of all complete patent submissions were not anticipated at all. In 1905, 1,308 specifications were wholly anticipated, meaning all their claims had already been patented before, while 8,238 specifications were partly anticipated, where one or several claims had been patented before. ‘Amendments following

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<sup>25</sup> We drew proportional samples from each category based on the breakdown of the patenting companies.

<sup>26</sup> We are unable to find balance sheets for nine companies that patented during our sample period. Four patented before 1905, four after 1905, and one in both periods.

search’ shows the outcomes of the examination procedure. ‘Amended by patentee’ shows the number of patents where the applicant amended their specification, either upon receipt of the examiner’s report or following an appeal. ‘Insertion of reference’ refers to those patents where a list of anticipating specifications was appended to the applicant’s specification by the Patent Office (a so-called “forced reference”). Over time, the level of whole anticipation and forced references declined, suggesting an improvement in the average quality of patent applications in the years after the introduction of examination.<sup>27</sup>

Table 1 presents total patenting statistics from PATSTAT separated into two periods. The first period we term ‘pre-reform’, which covers 1899–1904. The second period is ‘post-reform’, which covers 1905–1913. Within each period, we differentiate between patenting companies and patenting individuals based on PATSTAT’s classification of patentees and our sample of listed patenting companies. The summary statistics indicate differences in patenting companies’ characteristics over time. The most notable statistics are for ‘Patent stock’, which estimates the average number of patents granted to patentees. The introduction of patent examination coincides with an increase in the number of patents being obtained by firms, while the patent stock remains similar for individuals. Notably, our sample of patenting companies includes frequent users of the patent system. Our listed companies obtained an average of 12 patents in the pre-reform period, rising to an average of 20 after examination was introduced.<sup>28</sup>

The ‘Reference’ variable shows no change between periods for companies, but an increase in patents which reference prior art for individuals. The examination step was helping to improve the accuracy of patent claims for individuals. Our sample of patenting companies was already referencing prior patents more frequently in their specifications, a trend which increased following examination. Our findings imply that the introduction of examination had a stronger effect on the signal of novelty for innovative companies.<sup>29</sup>

‘Not granted’ refers to patent applications where a complete specification was filed, but the final sealing fee was not paid. Unsurprisingly, and as highlighted in Figure 1, there were few discernible instances of patentees abandoning their applications prior to 1905. After 1905, the rate of abandonment appears to be around one per cent for all companies and two per cent for individuals. This indicates that the examination step discouraged applicants from

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<sup>27</sup> The Patent Office published examination results up to the outbreak of World War I in 1914, after which they ceased to provide the same degree of detail in their annual publications.

<sup>28</sup> Even accounting for the outlier of British-Thomson Houston – which obtained more than 1,600 patents up to 1913 – our patenting companies increase their usage of the patent system.

<sup>29</sup> This is consistent with Allison and Hunter (2006), who find that increased examiner-added prior art references in the US led applicants to adapt by citing more prior art themselves.

proceeding with the lowest-quality patents. Notably, our patenting companies were much less likely to abandon their patents or to receive a forced reference.

[INSERT TABLE 2 HERE]

Table 2 presents annual patenting statistics for the firms in our dataset of listed firms only. Our sampled firms collectively obtain a total of 2,042 granted patents. After 1905, listed firms tend to receive a higher total number of patents than before 1905. The average number of patents received also increases compared to the pre-1905 period, although some of this change is due to several companies patenting prolifically. Table 2 also shows that patents granted following the introduction of examination are, on average, more heavily cited in later patents. This suggests that the introduction of patent examination was followed by a higher average quality of patents.

Overall, the data in Figure 2 and Tables 1 and 2 indicate that by reducing the number of low quality, spurious or “bad” patents, and highlighting patents that were indeed novel, the introduction of prior art search patent examination increased average patent quality and made patents a more reliable and meaningful signal of a firm’s innovative value, particularly for our dataset of listed patenting firms.

### *3.2 Financial data*

Table 3 reports summary statistics of key financial variables in our dataset. The data are split into patenting and non-patenting firms, before and after the introduction of patent examination. The main dependent variable we examine is the total debt-to-assets ratio, which captures a firm’s borrowing behaviour. This is computed by dividing the sum of all debt by total assets. Panel A describes the financial characteristics of all patenting firms and Panel B describes the financial characteristics of all non-patenting firms during the entire sample period 1899–1913. Before examination, the total debt-to-assets ratio of patenting firms is very similar to that of non-patenting firms, at 0.25 to 0.24, with a maximum of 0.62 in patenting firms and 0.66 in non-patenting firms. After the introduction of examination, the average debt ratio for patenting firms increased to 0.28, while the ratio for non-patenting firms remained unchanged. The maximum for patenting firms increased to 0.93, and to 0.78 for non-patenting firms.

[INSERT TABLE 3 HERE]

The data show that on average, firms possessing examined patents borrowed relatively more than firms patenting before the reform, or their non-patenting peers. This is consistent

with the hypothesis that rigorous patent examination may reduce information asymmetries, provide an enhanced signal of a firm's innovative value, and facilitate better access to credit for patenting firms. Notably these average changes are not reflected in all forms of debt. Prior to examination, patenting firms borrowed from capital markets at a similar level to non-patenting firms; the average bond debt-to-assets ratio for patenting firms was 0.16, compared to 0.15 for non-patenting firms. Both cohorts of firms had bank debt-to-assets ratios of 0.01 prior to 1905, and patenting firms received slightly more trade credit than non-patenting firms, at 0.08 versus 0.07. Following the introduction of patent examination, the average trade credit-to-assets ratio of both cohorts of firms increases by 0.01, and average bank borrowing remains constant. However, patenting firms increase their ratio of average bond/capital market borrowing from 0.16 to 0.18, while average capital market borrowing from non-patenting firms remains unchanged. This divergence suggests that the introduction of patent examination is specifically correlated with greater capital market access for patenting firms.

It is notable that before examination, the average total debt-to-assets ratio of patenting firms is similar to the average of non-patenting firms. This is not consistent with the stylised fact that innovative firms struggle to access debt finance. A unique facet of our sample period is that Britain enjoyed very well-developed corporate debt markets, and listed firms typically had good access to debt (Coyle and Turner, 2013; Hannah, 2015; Coyle, Musacchio and Turner, 2019). In addition, creditor rights in Britain were consistently strong during our period of analysis, particularly for bondholders (Hannah, 2007; Coyle and Turner, 2013). Research has shown that patenting companies raise more debt when creditor rights are strong, due to the increased collateral value of patents (Mann, 2018).

On average, patenting and non-patenting firms in our dataset have broad similarities in their characteristics, as well as some differences. Patenting firms tended to be larger and were slightly more likely to be family or director-controlled ('Family Controlled'), while non-patenting firms were slightly more likely to be based in London. Both cohorts of firms had similar levels of profitability (ROA, ROE).<sup>30</sup> We have a mix of young and old firms in the dataset, both patenting and non-patenting. This is possible because it was not unusual for early stage and even start-up companies to officially list on the stock exchange during the period of our analysis (Acheson, Coyle and Turner, 2016; Fjesme, Galpin and Moore, 2019). Table 4 shows the descriptive statistics for the pooled sample of all firms and years in our dataset.

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<sup>30</sup> Questions have been asked of the accuracy of financial statements published prior to the Companies Act 1948. These issues generally arose after our sample period. See Aldous et al. (2023, p. 143) for discussion.

[INSERT TABLE 4 HERE]

## 4. Empirical strategy and results

### 4.1 *Difference in means descriptive statistics*

In our empirical analysis, we treat the 1905 introduction of patent examination in Britain as an exogenous policy intervention in a difference-in-differences framework. We compare patenting with non-patenting firms throughout. First, we examine whether the differences observed in the average level of our key debt variables are statistically significant, using simple difference of means tests. Table 5 reports the results of difference of means tests on the average level of debt financing for patenting and non-patenting firms before and after the introduction of patent examination. We run means tests using the year of patent grant (Panel A) and patent application (Panel B) to identify patenting firms. The results in Table 6 confirm the trends in averages identified in Section 3; patenting firms on average borrow significantly more relative to their assets after the introduction of patent examination, whereas there is no significant change in non-patenting firm debt.

[INSERT TABLE 5 HERE]

Panel A shows that the average total debt-to-total assets ratio for firms with granted patents increases by a statistically significant 11.44 per cent after patent examination is introduced. There is a statistically insignificant 2.78 per cent increase in the average level of debt financing for non-patenting firms during the same period. Before patent examination was introduced, firms with patents borrowed 4.59 per cent more than non-patenting firms relative to assets (24.83% versus 23.74%). After the introduction of examination, average debt ratios for firms with examined patents were 13.36 per cent higher than those for non-patenting firms (27.67% versus 24.41%).

We split firms' total debt into capital market debt (i.e., bond debt), bank debt and trade credit. For patenting firms, we see statistically significant increases in both average 'bond' and 'trade' debt ratios after examination. Patenting firms' 'bond' debt ratios increased by 10.88 per cent (16.09% versus 17.84%) following the introduction of patent examination, while there is no significant change in the level of bond financing for non-patenting firms. After examination, patenting firms borrow 17.99 per cent more than non-patenting firms through capital market 'bond' debt (15.12% versus 17.84%). While there is evidence of an increase in non-patenting firm bank borrowing before and after 1905, there is no statistically significant change in average bank borrowing by patenting firms after patent examination is introduced.

Panel B reports difference in means tests using the year of patent application to identify when firms are treated in our dataset. The changes before and after patent examination for this group are similar to those in panel A, but of a larger magnitude. Comparing means between panels A and B, the data show that before examination is introduced, a firm that has filed a patent application borrows at the same level as non-patenting firms on average (0.2399 versus 0.2390), and less than firms with a granted patent (0.2399 versus 0.2483). After the introduction of examination, firms in the patent application group borrow, on average, at an almost identical level to those with granted patents (0.2765 versus 0.2767). This change before and after examination suggests that even as-yet unexamined patent filings may have an additional signalling effect in the new examination regime and implies an expectation, on the part of lenders, of a higher quality patent application pool following the introduction of examination.<sup>31</sup> These data are consistent with the hypothesis that patents can have an important signalling value beyond the basic collateral value associated with exclusionary property rights, and that examination improves this signal.

#### 4.2 Total debt ratio difference-in-differences regression results

Next, we introduce our more formal difference-in-differences analysis to examine the relationship between patent examination and firm financing more robustly. Our analysis is based on the following two-way fixed effects difference-in-differences model:

$$\begin{aligned}
Y_{it} = & \alpha Examination_t + \beta Patenting Firm_i \\
& + \gamma (Examination * Patenting Firm)_{it} \\
& + \theta X_{it} + \delta_i + \tau_t + \varepsilon_{it}
\end{aligned} \tag{1}$$

where  $Y$  is the total debt-to-total assets ratio;  $Examination$  is a dummy variable that equals 1 for the years in our dataset after patent examination was introduced (1905–1913) and zero otherwise;  $Patenting Firm$  is a dummy variable that takes the value of 1 for firms once they have obtained a patent in that patent regime (pre- or post-reform) and zero otherwise. Firms will only become ‘treated’ after 1905, once they have an examined and granted patent.  $X$  is a vector of firm-level control variables that account for characteristics that may influence firms’ financing decisions, such as profitability and growth opportunities (ROA, ROE, Tobin’s Q), self-financing capacity (Reserves and Retained Earnings/Assets), size (Log Total Share Book Value), maturity (Retained Earnings/Ordinary Equity), and Age;  $\delta_i$  is a firm fixed effect to

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<sup>31</sup> With the caveat that there is an overlap between the ‘filing’ and ‘grant’ groups because 22% of our firms had their patent filed and granted in the same year.

control for time-invariant heterogeneity across companies;  $t_t$  is a year fixed effect to control for macroeconomic or other time variant factors; and  $\varepsilon_{it}$  is the error term.<sup>32</sup> The subscript  $i$  indexes firms; and the subscript  $t$  indexes the time period. Parameter  $\gamma$  captures the relationship between patent examination and the financing decisions of patenting firms (with examined patents) relative to non-patenting firms, controlling for time, and firm-level characteristics. Regressions are run with and without standard errors clustered at the firm level.

An important identification assumption for the difference-in-differences estimates to be consistent is that, absent treatment, the change in the total debt-to-assets ratio for treated firms would not have been different from the change in the same ratio for control firms. Figure 3 shows the trend of the average level of total debt-to-assets and total bond debt-to-total-assets for patenting and non-patenting firms, before and after patent examination was introduced in 1905. This figure suggests that before patent examination, particularly for bond debt, the debt-to-assets ratio followed a similar trend for both patenting and non-patenting firms. Following patent examination, the debt level of non-patenting firms remains quite constant – however there is a clear upward shift in the debt levels of firms that patent in the new examination regime. As discussed in Section 3.2, patenting firms’ average debt-to-assets ratio increased from 0.25 pre-reform, to 0.28 post-reform. Tests of the pre-reform period reveal no statistically significant difference between the trend in the total debt-to-assets ratio of patenting and non-patenting firms before patent examination, suggesting that the trends for both groups are statistically parallel before 1905 (Appendix Table A3). Tests are consistent when using either the date of patent application or the date of patent grant.<sup>33</sup>

[INSERT FIGURE 3 HERE]

[INSERT TABLE 6 HERE]

Table 6 reports results from the main baseline difference-in-differences panel regressions on the total debt-to-total assets ratio of all firms, from 1899–1913. Our interaction term in column 1 (‘Patenting x Examination’) shows that firms patenting after 1905 have a 0.022 higher total debt-to-total assets ratio. In other words, firms that have an examined patent borrow significantly more compared to the pre-reform period and firms that did not patent. Columns 2-8 report our findings are consistent and robust to controlling for various firm characteristics that may also explain differences in borrowing. The estimated effect of an

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<sup>32</sup> A full list of the variables used in our analysis is reported in Appendix Table A2. This table includes precise variable definitions, and indicates the historical sources used in their construction.

<sup>33</sup> Tests using the Callaway and Sant’Anna (2021) estimator are discussed in Section 4.4 and shown in Appendix Table A8, confirming statistically parallel trends prior to patent examination.

examined patent increases to between 0.024 and 0.027, and is significant at both the 5 and 1 per cent level. Compared to a pre-reform average total debt-to-total assets ratio of 0.25 for patenting firms, this represents a relative increase in leverage of between 9.6 and 10.8 per cent following the grant of an examined patent. It is interesting to note that there is no significant relationship individually between patenting firms, or the post-1905 period, and the total debt ratio.

Consistent with what we would expect, columns 2 to 8 suggest that more profitable firms borrow less, firms with greater reserves and retained earnings relative to their size borrow less, and larger firms borrow less. Firm age does not have a significant effect on borrowing, all else constant. Column 4 shows that firms patenting in 1903 or 1904 – that is, after the new examination regime is announced in the 1902 Act, but before it is implemented – do not borrow more. This suggests that the result of patent examination itself, rather than anticipation of a new examination regime, is the key factor.

#### *4.3 Debt breakdown difference-in-differences regression results*

Firms in our study window accessed debt through capital markets (which tends to be longer maturity credit), bank lending (which is relationship-based and often shorter term), or using trade credit (which is short-term business-to-business borrowing). To investigate whether the average differences in source of credit observed in Sections 3 and 4.1 are robust, we analyse bond debt (debentures raised on capital markets) and non-bond debt (other debt) separately.

[INSERT TABLE 7 HERE]

[INSERT TABLE 8 HERE]

[INSERT TABLE 9 HERE]

Table 7 reports results from difference-in-differences panel regressions on the total bond debt-to-total assets ratio of all firms, and Table 8 the total other (non-bond) debt-to-total assets ratio of all firms, for 1899–1913. Table 7 suggests that patenting firms tend to borrow significantly less from capital markets, all else constant. However, the interaction term confirms that firms that patent in the new examination regime borrow more from capital markets, with a higher bond debt-to-total assets ratio in the range of 0.029 to 0.031. The average listed patenting firm borrowed 16.09 per cent of total assets on capital markets before patent examination was introduced in 1905 (Table 5). The results in Table 7, therefore, suggest that having an examined patent is associated with an 18.0 to 19.3 per cent increase in capital market borrowing for these firms. In contrast, regressions on the ratio of all other debt in Table 8

suggest that there is no significant relationship between having examined patents and access to non-capital-market debt.

Table 9 splits ‘other borrowing’ further into ‘bank borrowing’ and ‘trade credit’. The data show that there is no significant change in trade credit associated with companies which have examined patents (Panel B), however there is a negative relationship associated with examined patents and bank borrowing (Panel A). This apparent negative relationship with bank borrowing is driven by a divergence between patenting and non-patenting firms. Non-patenting firms borrow relatively more from banks and patenting firms relatively less, in the period following the introduction of examination (see Table 5). However, the levels of bank borrowing are very small, at around 3 per cent of total borrowing for patenting firms, and between 3 and 5 per cent for non-patenting firms.<sup>34</sup>

These results are consistent with the hypothesis that examined patents can act as a signalling device, through which the underlying value of an innovative firm is revealed to wider market participants. This reduces information asymmetries and enables greater access to capital market debt financing for patenting firms. These results suggest that an examined patent’s value is not just derived from the exclusionary property right, which patentees enjoyed before examination, but also as a signal of the value of underlying innovation.

We propose two explanations for the observed negative relationship between firms in possession of examined patents and their rate of bank borrowing. First, it is possible that relationship-based banking may mean that banks were already more aware than other market participants of the innovative prospects of firms, which limited their capacity for further bank borrowing. For capital market creditors, patent examination may effectively act as a substitute to the relationship-based information banks enjoy (Saidi and Žaldokas, 2017). Additionally, innovative firms may prefer capital market debt, which is typically more arm’s-length, of larger scale, and longer term. We suggest that examined patents enabled firms to more easily pursue capital market debt financing options, which they preferred to using banks.

[INSERT TABLE 10 HERE]

Table 10, column 1, examines whether there is a relationship between having an examined patent and the cost of capital market debt. The dependent variable is the weighted average cost of debt measured by the weighted average coupon payments on a firm’s issued bonds. We find there is no significant relationship between having an examined patent and the

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<sup>34</sup> This is consistent with studies showing that banks were not a particularly important source of finance for firms in this period (Collins and Baker, 2001; 2003).

cost of debt capital in our dataset. This is likely because debenture holders in the UK in this period very rarely lost money due to default. Debentures were secured by all present and future assets of a firm and holders ranked ahead of all other creditors, meaning that firms with successful debt issues tended to borrow at relatively similar rates (Coyle and Turner, 2013). Interestingly, Table 10 columns 2 and 3 report a negative relationship between holding examined patents and a firm's ratio of capital raised through common and preference shares. This suggests firms with an examined patent specifically raised additional capital through debt markets in preference to equity, much as pecking order theory would predict.

The positive relationship between firms with examined patents and the ratio of debt to assets, and the negative relationship with the ratio of equity, raises the question of whether additional access to debt markets led innovative firms to adjust their capital structure by switching from equity to debt, or whether it was enabling overall firm growth. If examined patents were indeed a better signal of innovation quality, and facilitated greater funding of this innovation, we would expect that firm growth would follow. Table 11 examines whether there is a relationship between having an examined patent and firm size, measured by the log of total assets. Columns 2 to 5 control for various firm characteristics, including total issued equity in column 5. We can see that there is no significant relationship between the examination period and firm size, and a weak negative relationship between patenting and firm size. However, firms with examined patents are significantly larger, suggesting that additional debt facilitated the growth of innovative firms, rather than just a restructuring of capital.

[INSERT TABLE 11 HERE]

#### *4.4 Further robustness exercises*

To further test the robustness of our results, we examine the data using several alternative specifications. First, in Appendix Table A4, we analyse the data using a pooled regression. This also enables us to test the effect of additional dummy variable covariates. It is possible that firms that were family-controlled may have had a different attitude to firm financing than those that were not. It is also possible that firms located in London, closer to primary capital markets, may have had easier access to debt financing than firms that were not. The patenting firms in our dataset come from the 'Commercial & Industrial' and the 'Iron, Coal and Steel' categories used by the London Stock Exchange to classify its listings; the changes in debt ratios that we see could be industry-driven. It is plausible that our principal finding – that patenting

firms borrow relatively more after the introduction of patent examination – could be driven by changes within these additional firm characteristics.

Results in Appendix Table A4 show either no relationship or a limited significant relationship between family-controlled or London-based firms and debt-to-asset ratios. Firms in the Iron, Coal and Steel sector *do* borrow significantly more relative to assets than other firms in the dataset. After controlling for these covariates, our main results remain; following the introduction of patent examination, firms with examined patents borrow significantly more, and significantly more from capital markets, than those that do not.

Second, we explore whether our results are biased by the characteristics of our randomly selected control group of non-patenting firms. We use matching and rebalancing to ensure that any differences in total debt-to-total asset outcomes are attributable to the treatment (examined patent), rather than any underlying differences in characteristics between our control sample and patenting group. We also adopt a stricter definition of the control group, excluding non-patenting firms from the first period that become patenting for the first time in the post-reform period, as well as firms that patent before examination but not after. Results for these regressions are reported in Appendix Table A5.

Column 1 of Appendix Table A5 reports results following a propensity score matching (PSM) procedure. Propensity scores were estimated using a logistic regression model where matching was based on firm profitability (ROA), self-financing ability (Total Reserves/Total Assets) and size (the natural logarithm of Summed Equity), controlling for each year, prior to the introduction of patent examination. Using the estimated propensity scores, nearest-neighbour matching, with one match per treated unit, was applied to generate the matched sample. The coefficient on the interaction term in Appendix Table A5 is highly consistent with our earlier results.

Column 2 reports results following an entropy balancing (EB) procedure. EB reweights the control group so that the covariates have the same distribution as in the treated group. This ensures that the control group is comparable to the treated group in terms of pre-treatment characteristics. The control sample was again balanced based on firm profitability (ROA), self-financing ability (Total Reserves/Total Assets) and size (the natural logarithm of Issued Share Capital), each year prior to the introduction of patent examination. The coefficient on the interaction term in Appendix Table A5 is again highly consistent with our earlier results.

Column 3 reports results of a regression where the control group constitutes only those firms that *never* patented in either the pre- or post-reform period. Focusing on “never-

innovative” firms allows us to exclude firms that change their patenting strategy to coincide with the new examination system. Results are consistent with our main analysis.

Third, we rerun our headline regressions using an alternative measure of firm profitability: Return on Equity (ROE). This is calculated by dividing net profit by the book value of the total issued share capital. This measure more accurately reflects returns to equity holders, whose stakes are most directly affected by leverage decisions.<sup>35</sup> Results are reported in Appendix Table A6. They are generally consistent with the results in our main analysis.

Next, we replicate key results from the paper’s main analysis, using the patent application date rather than the grant date, to determine whether a firm was affected by the new patent examination regime. This exercise also accounts for patents that were filed before the January 1905 regime change but granted in the new regime. Essentially, it constitutes a stricter definition of the regime change timing. These results are reported in Appendix Table A7 and show effects of a very similar scale, direction and significance to our main analysis.

A growing literature has shown that two-way fixed-effects (TWFE) difference-in-differences models can yield biased estimates when treatment is staggered across units and time. In our setting, although patent examination was introduced in 1905, firms apply for patents at different times, resulting in some staggered treatment dates in our data. To address this concern, we implement the difference-in-differences estimator developed by Callaway and Sant’Anna (2021), which accommodates heterogeneity in treatment timing and effects by estimating group-time average treatment effects (ATTs), and aggregating them using valid comparison groups. This is achieved with a series of cross-sectional regressions for each cohort-time pair, comparing treated and untreated firms, and then aggregating effects using appropriate weights.

Results using this estimator are shown in Appendix Table A8. The estimates represent average treatment effects before and after firms are granted an examined patent. This allows us to examine pre-trends and post-treatment changes in firm leverage, accounting for staggered treatment timing. The estimated pre-treatment coefficients are small and not statistically significant at standard levels, confirming our earlier evidence of the absence of systematic pre-trends in the data. Following the grant of an examined patent, firms show a statistically significant increase in leverage, again supporting our earlier findings. The magnitude of this effect is almost identical to our main finding in Table 6 (0.024 versus 0.023).

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<sup>35</sup> ROE will also reduce potential measurement error from any potential inaccuracies in reported assets in balance sheets (following Aldous et al., 2023).

To further assess the robustness of our main difference-in-differences results, we run a simulation-based placebo test, with randomised treatment assignment. The goal is to determine whether our observed treatment effects could plausibly arise by chance, due to noise or model structure, rather than reflecting a genuine causal impact of patent examination on firm leverage. We conduct 1,000 placebo simulations in which we randomly assign firms as patenting firms and randomly assign their patenting year. This random assignment is constrained to match the overall proportion of patenting firms in the real data (i.e., 41.4%). For each simulated dataset, we re-estimate our baseline regression model, focusing on the interaction term that identifies the treatment effect (i.e., examined patent). We then collect the estimated coefficients and p-values from each placebo regression to generate a distribution of treatment effects.

The distribution of placebo estimates of examined patents is shown in Appendix Table A9 and Figure A1. Placebo estimates are centred below zero, with only 6.6 per cent of simulations yielding a statistically significant examined patent coefficient. Only 13 of 1,000 simulations, or 1.3 per cent, yield treatment effects that are both statistically significant and positive, the direction required to explain our actual findings. This provides strong evidence that our estimated effect is unlikely to be driven by chance, reinforcing our results.

## **5. Conclusion**

Access to finance is a significant barrier inhibiting the growth of innovative firms and the pace of innovation. This paper examines whether the design of the patent system can improve access to finance for innovative firms. Exploiting the introduction of prior art search patent examination in the UK in 1905, which extended the involvement of the UK state in the quality control of new patentable innovations, we find that patenting firms had greater access to debt finance after their patents underwent examination. Appendix Table A10 summarises our key insights along several dimensions by contrasting what we think are the pre- versus post-reform equilibria.

Specifically, our results show that firms with examined patents benefited from greater access to capital market borrowing, rather than other sources such as bank loans or trade credit. By raising the average quality of patent grants through the screening out of low-quality, or highlighting non-novel, applications, patent examination enhanced the value of patents as assets that embody otherwise intangible knowledge capital. This screening process reduced information asymmetry, thereby reinforcing the signal of a firm's innovation performance to investors and enhancing the credibility of patents as collateral. In the event of bankruptcy, patent rights could be appropriated to help recover the value of bondholders' claims, thus

mitigating risks associated with investing in innovative firms. This dual function of patents, as both signals of innovation quality and valuable assets, underscores the broader economic role of rigorous patent examination.

Our findings suggest that examined patents facilitate innovative firms' strategic use of debt financing, particularly from capital markets, over alternative sources such as equity or bank loans. This debt financing aligns with the pecking order theory, as firms seek to minimise the costs associated with relinquishing ownership or control rights. It also aligns with the argument that the signalling value of a patent can substitute for a relationship-based lender's "soft" information. Importantly, the increased borrowing observed among patenting firms is associated with firm growth, suggesting that patent examination enabled innovative firms to scale and capitalise on their inventions.

While increased borrowing and firm growth are encouraging signs of investment in innovative opportunities, they also bring heightened financial risk. Firms with higher debt levels may face greater vulnerability to economic downturns, particularly if their patented inventions fail to generate the anticipated revenue. A longer-term evaluation of the financial performance and resilience of these firms would be an interesting direction for future research.

Our findings underscore the importance of government policy in reducing financial market failures associated with information asymmetry. They also highlight the importance of aligning patent system design with financial market structures, to support the growth of innovative firms. While our historical setting offers a valuable quasi-experimental environment for examining patents as signals, the nature of financial markets during our sample period is particularly significant. For the majority of the twentieth century, well-developed corporate debt markets in Britain enabled both new and established firms to raise funds from investors through debentures. This market structure likely amplified the signalling value of patent examination. In the latter part of the twentieth century, the UK corporate bond market transitioned to a smaller, less accessible market for borrowers and lenders. Therefore, the benefits of rigorous patent examination may not materialise to the same extent without ensuring complementary financial market structures to connect innovative firms with potential lenders.

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## Tables

Table 1. Summary statistics of all British patenting activity, 1899–1913

Variable	Pre-reform						Post-reform					
	Individuals (57,277)		Firms (3,107)		Sample Firms (95)		Individuals (86,357)		Firms (7,189)		Sample Firms (121)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Patent stock	1.80	10.14	2.31	13.02	12.48 (6.10)	62.50 (9.15)	1.95	7.36	2.91	15.26	20.64 (12.58)	89.93 (17.55)
Reference	4%	17%	8%	24%	15%	36%	9%	29%	9%	29%	19%	39%
Void	-	-	-	-	-	-	0%	1%	0%	1%	-	-
Not Granted	0%	1%	0%	3%	-	-	3%	16%	1%	11%	0%	4%
Forward Citation	0.14	0.50	0.14	0.45	0.09	0.40	0.25	0.90	0.25	0.79	0.19	0.61
Forced Reference	-	-	-	-	-	-	2%	15%	1%	10%	0%	4%

*Notes:* ‘Pre-reform’ covers 1899–1904; ‘post-reform’ covers 1905–1913. ‘Individuals’ refers to patents held by a person, ‘Firms’ refers to patents held by any kind of commercial firm, and ‘Sample Firms’ refers to our population of patenting firms listed in the LSE. ‘Patent stock’ is the total number of patents held by each unique person or firm in the period in question. The numbers in the parentheses represent the patent stock when the ‘British Thomson-Houston’ company has been removed, as it is an outlier, having obtained over 1,000 patents in our period of observation. ‘Reference’ is a crude measure of how many references each complete specification makes to other patents (e.g., ‘7%’ means that 7% of patents granted had at least one reference to another patent). ‘Void’ are the percentage of patents indicating the patent was void in the abstract text. ‘Not Granted’ refers to the percentage of patents where the sealing fee was listed as not paid in the abstract text. ‘Forward Citation’ is the average number of forward citations from future patents received by each patent. ‘Forced reference’ is the percentage of patents which contain a list of references to other specifications as appended by the Patent Office.

*Sources:* Authors’ calculations using data from PATSTAT.

Table 2. Patenting statistics of listed patenting firms, 1899–1913

Year	Total Patents Granted					Total Citations				
	Mean	Sum	Max	Min	Count	Mean	Sum	Max	Min	Count
1899	2.13	17	7	1	8	0.25	2	1	0	8
1900	2.73	30	9	1	11	0.73	8	4	0	11
1901	1.86	26	4	1	14	0.07	1	1	0	14
1902	5.26	121	81	1	23	0.22	5	3	0	23
1903	4.12	103	37	1	25	0.36	9	3	0	25
1904	4.26	115	46	1	27	0.56	15	3	0	27
1905	6.79	265	175	1	39	0.67	26	9	0	39
1906	6.54	229	133	1	35	0.77	27	10	0	35
1907	6.86	240	155	1	35	0.77	27	4	0	35
1908	5.64	203	121	1	36	0.39	14	9	0	36
1909	4.68	192	87	1	41	0.68	28	6	0	41
1910	4.10	213	66	1	52	1.13	59	12	0	52
1911	4.60	193	54	1	42	1.19	50	10	0	42
1912	6.30	233	70	1	37	1.38	51	15	0	37
1913	7.40	222	120	1	30	1.57	47	19	0	30
Total	5.28	2,402	-	-	455	0.81	369	-	-	455

*Notes:* Table reports both total patents granted, and the proportion of patents granted that received a citation in subsequent patent applications (forward citations from future inventions) for our sample of listed patenting firms. Mean, standard deviation, minimum, maximum and total number of firm-year observations are shown.

*Sources:* Authors' calculations using data from PATSTAT.

Table 3. Descriptive statistics of patenting and non-patenting firms (grant date)

*Panel A: Patenting firms*

Variable	Pre-Reform (1899–1904)					Post-Reform (1905–1913)				
	N	Mean	Std. dev.	Min	Max	N	Mean	Std. dev.	Min	Max
Total Assets	150	1,901,681	2,498,363	122,959	9,152,975	422	2,446,829	3,885,251	111,698	22,600,000
Net Profit	150	94,853	136,633	-12,524	723,594	422	137,601	328,212	-152,132	3,028,278
Retained Earnings	150	18,128	31,778	-49,762	191,074	422	38,605	84,728	-169,220	840,462
Total Reserves	150	122,155	187,709	0.0	958,273	421	231,854	656,552	-	7,100,000
Issued Share Capital	150	1,126,782	1,497,560	80,000	5,718,670	421	1,391,146	2,415,023	70,000	15,500,000
Total Debt	150	548,934	845,140	1,262	3,383,415	422	691,042	1,079,207	-	8,658,410
Other Debt	150	149,464	213,398	-	1,219,842	422	174,635	243,986	-	2,011,883
Bond Debt	150	399,470	726,173	-	3,200,000	422	516,408	903,929	-	8,047,012
Cash Total	150	69,580	134,359	-	815,662	422	92,649	147,533	-	1,184,712
Total Debt/Total Assets	150	0.25	0.13	0.00	0.62	422	0.28	0.15	0.00	0.93
Bond Debt/Total Assets	150	0.16	0.12	0.00	0.49	422	0.18	0.14	0.00	0.87
Other Debt/Total Assets	150	0.09	0.07	0.00	0.31	422	0.10	0.08	0.00	0.55
Bank Debt/Total Assets	150	0.01	0.02	0.00	0.13	422	0.01	0.02	0.00	0.19
Trade Credit/Total Assets	150	0.08	0.06	0.00	0.31	422	0.09	0.07	0.00	0.53
Maturity Ratio	145	0.03	0.06	-0.22	0.23	414	0.07	0.11	-0.32	0.94
ROE	150	0.10	0.07	-0.03	0.46	421	0.09	0.08	-0.13	0.42
ROA	150	0.06	0.04	-0.01	0.25	422	0.05	0.04	-0.06	0.24
Tobin's Q	150	0.92	0.46	0.31	4.70	419	1.01	3.90	0.00	75.38
Age	150	12.95	9.65	2.00	40.00	422	16.73	11.33	1.00	59.00
London HQ	150	0.49	0.50	0.00	1.00	422	0.40	0.49	0.00	1.00
Family Controlled	150	0.41	0.49	0.00	1.00	422	0.44	0.50	0.00	1.00

*Continued overleaf...*

Panel B: Non-patenting firms

Variable	Pre-Reform (1899–1904)					Post-Reform (1905–1913)				
	N	Mean	Std. dev.	Min	Max	N	Mean	Std. dev.	Min	Max
Total Assets	767	887,108	1,231,543	54,743	14,700,000	1,170	969,268	1,344,650	76,243	19,900,000
Net Profit	761	50,134	115,069	-57,150	2,339,787	1,161	52,504	140,691	-73,759	2,795,925
Retained Earnings	759	8,698	26,432	-109,323	272,104	1,159	14,242	45,932	-187,729	836,234
Total Reserves	756	54,945	119,977	-	1,650,000	1,147	90,239	258,118	-	5,400,000
Issued Share Capital	767	537,055	701,737	39,930	5,852,240	1,165	565,605	778,703	50,000	10,000,000
Total Debt	767	223,223	391,786	-	3,668,431	1,170	243,634	356,687	-	3,034,491
Other Debt	767	62,796	90,568	-	945,673	1,170	81,819	110,389	-	942,805
Debentures	767	160,428	344,150	-	3,200,000	1,170	161,815	293,436	-	2,250,000
Cash Total	767	33,590	63,713	-	1,008,680	1,170	35,139	78,980	-	1,409,293
Total Debt/Total Assets	767	0.24	0.16	0.00	0.66	1,170	0.24	0.16	0.00	0.78
Bond Debt/Total Assets	767	0.15	0.15	0.00	0.60	1,170	0.15	0.15	0.00	0.61
Other Debt/Total Assets	767	0.08	0.08	0.00	0.55	1,170	0.09	0.09	0.00	0.49
Bank Debt/Total Assets	767	0.01	0.02	0.00	0.27	1,170	0.01	0.04	0.00	0.37
Trade Credit/Total Assets	767	0.07	0.08	0.00	0.55	1,170	0.08	0.08	0.00	0.49
Maturity Ratio	732	0.04	0.09	-0.42	0.92	1,121	0.06	0.18	-0.57	2.28
ROE	761	0.09	0.10	-0.36	0.96	1,156	0.09	0.10	-0.12	1.50
ROA	761	0.06	0.05	-0.29	0.49	1,161	0.05	0.05	-0.07	0.43
Tobin's Q	767	1.26	5.26	0.17	63.72	1,166	0.99	3.25	0.00	55.98
Age	767	13.88	12.06	0.00	68.00	1,170	19.95	13.03	0.00	76.00
London HQ	767	0.59	0.49	0.00	1.00	1,170	0.59	0.49	0.00	1.00
Family Controlled	767	0.36	0.48	0.00	1.00	1,170	0.38	0.49	0.00	1.00

Notes: This table shows the annual summary statistics of patenting and non-patenting firms before the introduction of patent examination (1899–1904) and after the introduction of patent examination in Britain in 1905 (1905–1913). ‘Pre-reform’, firms are only categorised as a ‘patenting’ firm once they have been granted an *unexamined* patent. ‘Post-reform’, firms are only categorised as a ‘patenting’ firm once they have been granted an *examined* patent. Mean, standard deviation, minimum, maximum and total number of firm-year observations are shown. See Appendix Table A2 for variable definitions and sources.

Table 4. Descriptive statistics of full sample, 1899–1913

Variable	N	Mean	Std. dev.	Min	Max
Total Assets	2,509	1,248,413	2,134,057	54,743	22,600,000
Net Profit	2,494	68,727	183,374	-152,132	3,028,278
Retained Earnings	2,490	16,915	50,723	-187,729	840,462
Total Reserves	2,474	105,488	337,971	0	7,100,000
Issued Share Capital	2,503	729,341	1,285,480	39,930	15,500,000
Total Debt	2,509	330,898	613,098	0.00	8,658,410
Other Debt	2,509	95,659	150,085	0.00	2,011,883
Debentures	2,509	235,239	513,748	0.00	8,047,012
Cash Total	2,509	46,397	96,824	0.00	1,409,293
Total Debt/Total Assets	2,509	0.25	0.16	0.00	0.93
Bond Debt/Total Assets	2,509	0.16	0.14	0.00	0.87
Other Debt/Total Assets	2,509	0.09	0.08	0.00	0.55
Bank Debt/Total Assets	2,509	0.01	0.03	0.00	0.37
Trade Credit/Total Assets	2,509	0.08	0.07	0.00	0.55
Maturity Ratio	2,412	0.05	0.14	-0.57	2.28
ROE	2,488	0.09	0.09	-0.36	1.50
ROA	2,494	0.05	0.05	-0.29	0.49
Tobin's Q	2,502	1.07	3.99	0.00	75.38
Age	2,509	17.14	12.59	0	76
London HQ	2,509	0.55	0.50	0	1
Family Controlled	2,509	0.39	0.49	0	1

*Notes:* This table shows the annual summary statistics of all firms in our dataset from 1899–1913. Mean, standard deviation, minimum, maximum and total number of firm-year observations are shown. See Appendix Table A2 for variable definitions and sources.

Table 5. Comparison of average debt ratios, pre- versus post-reform

*Panel A: Patent Grant Date*

Variable	Pre-Reform	Post-Reform	Difference		N
Total Debt/Total Assets					
Patenting Firms	0.2483	0.2767	0.0284	**	572
Non-Patenting Firms	0.2374	0.2441	0.0066		1,937
Bond Debt/Total Assets					
Patenting Firms	0.1609	0.1784	0.0175	*	572
Non-Patenting Firms	0.1540	0.1512	-0.0028		1,937
Other Debt/Total Assets					
Patenting Firms	0.0874	0.0984	0.0109	*	572
Non-Patenting Firms	0.0834	0.0929	0.0095	*	1,937
Bank Debt/Total Assets					
Patenting Firms	0.0081	0.0068	-0.0012		572
Non-Patenting Firms	0.0086	0.0130	0.0044	***	1,937
Trade Credit/Total Assets					
Patenting Firms	0.0788	0.0914	0.0125	**	572
Non-Patenting Firms	0.0731	0.0783	0.0043		1937

*Panel B: Patent Filing Date*

Variable	Pre-Reform	Post-Reform	Difference		N
Total Debt/Total Assets					
Patenting Firms	0.2399	0.2765	0.0365	***	655
Non-Patenting Firms	0.2390	0.2431	0.0041		1,854
Bond Debt/Total Assets					
Patenting Firms	0.1534	0.1763	0.0229	**	655
Non-Patenting Firms	0.1556	0.1511	-0.0045		1,854
Other Debt/Total Assets					
Patenting Firms	0.0865	0.1002	0.0136	**	655
Non-Patenting Firms	0.0835	0.0920	0.0085	**	1,854
Bank Debt/Total Assets					
Patenting Firms	0.0074	0.0082	0.0008		655
Non-Patenting Firms	0.0088	0.0126	0.0038	***	1,854
Trade Credit/Total Assets					
Patenting Firms	0.0787	0.0918	0.0131	**	655
Non-Patenting Firms	0.0737	0.0777	0.0040		1,854

*Notes:* This table compares the average debt-to-assets ratios for patenting and non-patenting firms before and after the introduction of patent examination in 1905. ‘Pre-reform’ is the average debt-to-assets ratio for firms from 1899–1904. ‘Post-reform’ is the average debt-to-assets ratio for firms from 1905–1913. ‘Bond Debt’ is the total corporate bond/debenture borrowing; ‘Other Debt’ is debt excluding corporate bond borrowing; ‘Bank Debt’ is all bank borrowing; and ‘Trade Credit’ is all borrowing/credit from trade. Panel A uses the date a patent is granted to identify a patenting firm. Panel B uses the date a patent application is filed (application date) to identify a patenting firm. See Appendix Table A2 for variable definitions and sources. Significance of difference of means tests are indicated as \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

Table 6. Effect of patent examination on access to total debt

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patenting Firm	0.001 (0.012)	0.035 (0.099)	0.035 (0.091)	0.035 (0.099)	0.013 (0.101)	0.013 (0.092)	0.030 (0.100)	0.021 (0.100)
Examination Years	-0.008 (0.009)	-0.008 (0.008)	-0.008 (0.007)	0.006 (0.014)	-0.009 (0.008)	-0.009 (0.007)	-0.010 (0.008)	-0.010 (0.008)
Patenting x Examination	0.022* (0.012)	0.024** (0.011)	0.024*** (0.007)	0.024* (0.013)	0.024** (0.011)	0.024*** (0.007)	0.024** (0.011)	0.027** (0.011)
Anticipation Patenting				-0.015 (0.015)				
Anticipation Years				0.006 (0.038)				
Anticipation Effect				-0.004 (0.013)				
ROA		-0.393*** (0.070)	-0.393*** (0.047)	-0.393*** (0.070)	-0.433*** (0.069)	-0.433*** (0.050)	-0.429*** (0.069)	-0.318*** (0.065)
Total Reserves/Total Assets		-0.466*** (0.070)	-0.466*** (0.034)	-0.464*** (0.070)	-0.459*** (0.072)	-0.459*** (0.035)	-0.461*** (0.072)	
(Total Reserves + Retained Earnings)/Total Assets								-0.390*** (0.066)
Age		-0.000 (0.007)	-0.000 (0.007)	-0.000 (0.007)	0.001 (0.008)	0.001 (0.007)	-0.000 (0.008)	0.001 (0.008)
ln (Issued Share Capital)		-0.084*** (0.021)	-0.084*** (0.009)	-0.084*** (0.021)	-0.091*** (0.021)	-0.091*** (0.009)	-0.095*** (0.022)	-0.086*** (0.022)
Maturity Ratio					0.036 (0.039)	0.036 (0.026)	0.032 (0.039)	
Tobin's Q							0.000 (0.000)	
Constant	0.254*** (0.008)	1.381*** (0.275)	1.381*** (0.135)	1.379*** (0.278)	1.452*** (0.278)	1.452*** (0.138)	1.521*** (0.285)	1.384*** (0.288)
Observations	2,509	2,469	2,469	2,469	2,391	2,391	2,386	2,467
R-squared	0.028	0.143	0.143	0.144	0.150	0.150	0.153	0.129
Number of Firms	295	293	293	293	287	287	287	292
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	NO	YES	YES	NO	YES	YES

Notes: This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is Total Debt/Total Assets. 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. 'Anticipation Effect' is an interaction to test any additional anticipatory effect of patenting after the announcement of patent examination legislation, but before its implementation in 1905 (i.e., covering 1903 and 1904). See Appendix Table A2 for variable definitions and sources. (Clustered) robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 7. Effect of patent examination on access to capital market (bond) debt

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Patenting Firm	-0.017* (0.009)	-0.017** (0.008)	-0.017*** (0.006)	-0.017* (0.009)	-0.017*** (0.006)	-0.018** (0.009)
Examination Years	-0.009 (0.010)	0.008 (0.074)	0.008 (0.071)	0.002 (0.077)	0.002 (0.073)	-0.001 (0.076)
Patenting x Examination	0.029** (0.013)	0.031*** (0.012)	0.031*** (0.005)	0.030** (0.012)	0.030*** (0.005)	0.033*** (0.012)
ROA		-0.274*** (0.056)	-0.274*** (0.037)	-0.287*** (0.060)	-0.287*** (0.039)	-0.228*** (0.052)
Total Reserves/Total Assets		-0.285*** (0.059)	-0.285*** (0.027)	-0.270*** (0.059)	-0.270*** (0.027)	
(Total Reserves + Retained Earnings)/Total Assets						-0.237*** (0.055)
Age		0.000 (0.006)	0.000 (0.005)	0.001 (0.006)	0.001 (0.005)	0.001 (0.006)
ln (Issued Share Capital)		-0.065*** (0.022)	-0.065*** (0.007)	-0.070*** (0.023)	-0.070*** (0.007)	-0.066*** (0.022)
Maturity Ratio				0.020 (0.038)	0.020 (0.021)	
Constant	0.161*** (0.008)	1.020*** (0.281)	1.020*** (0.106)	1.084*** (0.289)	1.084*** (0.108)	1.021*** (0.288)
Observations	2,509	2,469	2,469	2,391	2,391	2,467
R-squared	0.022	0.109	0.109	0.110	0.110	0.099
Number of Firms	295	293	293	287	287	292
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	NO	YES	NO	YES

*Notes:* This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is Bond Debt/Total Assets. 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. See Appendix Table A2 for variable definitions and sources. (Clustered) robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 8. Effect of patent examination on access to non-capital market (other) debt

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Patenting Firm	0.009 (0.005)	0.009 (0.005)	0.009* (0.005)	0.008 (0.006)	0.008 (0.006)	0.008 (0.005)
Examination Years	0.010 (0.008)	0.027 (0.072)	0.027 (0.070)	0.011 (0.072)	0.011 (0.072)	0.022 (0.071)
Patenting x Examination	-0.007 (0.006)	-0.007 (0.006)	-0.007 (0.005)	-0.006 (0.006)	-0.006 (0.005)	-0.006 (0.006)
ROA		-0.119** (0.051)	-0.119*** (0.036)	-0.146*** (0.054)	-0.146*** (0.039)	-0.090* (0.048)
Total Reserves/Total Assets		-0.181*** (0.051)	-0.181*** (0.026)	-0.189*** (0.053)	-0.189*** (0.027)	
(Total Reserves + Retained Earnings)/Total Assets						-0.153*** (0.046)
Age		-0.000 (0.005)	-0.000 (0.005)	0.001 (0.005)	0.001 (0.005)	-0.000 (0.005)
ln (Issued Share Capital)		-0.019 (0.012)	-0.019*** (0.007)	-0.021 (0.013)	-0.021*** (0.007)	-0.020 (0.012)
Maturity Ratio				0.016 (0.024)	0.016 (0.020)	
Constant	0.092*** (0.005)	0.361** (0.163)	0.361*** (0.104)	0.368** (0.170)	0.368*** (0.107)	0.363** (0.165)
Observations	2,509	2,469	2,469	2,391	2,391	2,467
R-squared	0.023	0.049	0.049	0.053	0.053	0.045
Number of Firms	295	293	293	287	287	292
Time FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	NO	YES	NO	YES

*Notes:* This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is Non-Capital Market Debt/Total Assets. 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. See Appendix Table A2 for variable definitions and sources. (Clustered) robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 9. Effect of patent examination on access to bank debt, and trade credit

*Panel A: Bank debt*

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Patenting Firm	0.003* (0.002)	0.003* (0.002)	0.003 (0.003)	0.003* (0.002)	0.003 (0.003)	0.003* (0.002)
Examination Years	0.003 (0.006)	0.039 (0.026)	0.039 (0.040)	0.041 (0.027)	0.041 (0.041)	0.038 (0.025)
Patenting x Examination	-0.007** (0.003)	-0.007** (0.003)	-0.007** (0.003)	-0.007** (0.003)	-0.007** (0.003)	-0.007** (0.003)
ROA		-0.069*** (0.021)	-0.069*** (0.020)	-0.067*** (0.023)	-0.067*** (0.022)	-0.060*** (0.020)
Total Reserves/Total Assets		-0.052** (0.026)	-0.052*** (0.015)	-0.053** (0.026)	-0.053*** (0.015)	
(Total Reserves + Retained Earnings)/Total Assets						-0.047* (0.024)
Age		-0.002 (0.002)	-0.002 (0.003)	-0.003 (0.002)	-0.003 (0.003)	-0.002 (0.002)
ln (Issued Share Capital)		-0.009 (0.007)	-0.009** (0.004)	-0.008 (0.007)	-0.008* (0.004)	-0.009 (0.007)
Maturity Ratio				-0.006 (0.012)	-0.006 (0.012)	
Constant	0.010*** (0.004)	0.149* (0.084)	0.149** (0.059)	0.143 (0.088)	0.143** (0.061)	0.151* (0.084)
Observations	2,509	2,469	2,469	2,391	2,391	2,467
R-squared	0.015	0.026	0.026	0.026	0.026	0.026
Number of Firms	295	293	293	287	287	292
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	NO	YES	NO	YES

*Continued overleaf...*

Panel B: Trade credit

Variable	(7)	(8)	(9)	(10)	(11)	(12)
Patenting Firm	0.004 (0.005)	0.004 (0.005)	0.004 (0.005)	0.004 (0.005)	0.004 (0.005)	0.002 (0.006)
Examination Years	0.007 (0.007)	-0.022 (0.064)	-0.022 (0.061)	-0.041 (0.065)	-0.041 (0.063)	-0.011 (0.009)
Patenting x Examination	0.001 (0.005)	0.002 (0.005)	0.002 (0.005)	0.003 (0.005)	0.003 (0.005)	0.004 (0.005)
ROA		-0.037 (0.045)	-0.037 (0.032)	-0.062 (0.047)	-0.062* (0.034)	-0.016 (0.042)
Total Reserves/Total Assets		-0.135*** (0.037)	-0.135*** (0.023)	-0.143*** (0.039)	-0.143*** (0.023)	
(Total Reserves + Retained Earnings)/Total Assets						-0.112*** (0.034)
Age		0.003 (0.005)	0.003 (0.005)	0.004 (0.005)	0.004 (0.005)	-0.011 (0.009)
ln (Issued Share Capital)		-0.010 (0.009)	-0.010 (0.006)	-0.012 (0.009)	-0.012* (0.006)	-0.026 (0.064)
Maturity Ratio				0.017 (0.020)	0.017 (0.018)	0.004 (0.005)
Constant	0.081*** (0.004)	0.194 (0.122)	0.194** (0.091)	0.207* (0.125)	0.207** (0.093)	0.195 (0.123)
Observations	2,509	2,469	2,469	2,391	2,391	2,467
R-squared	0.015	0.031	0.031	0.036	0.036	0.028
Number of Firms	295	293	293	287	287	292
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	NO	YES	NO	YES

Notes: This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is Bank Debt/Total Assets in Panel A, and Trade Credit/Total Assets in Panel B. 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. See Appendix Table A2 for variable definitions and sources. (Clustered) robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 10. Effect of patent examination on the cost of debt, and on equity financing

Variable	(1) Weighted Average Debt Cost	(2) Total Common/ Total Assets	(3) Total Preference/ Total Assets
Patenting Firm	0.033 (0.053)	0.002 (0.006)	0.011* (0.006)
Examination Years	-0.534 (0.814)	-0.009 (0.053)	0.059 (0.054)
Patenting x Examination	0.042 (0.030)	-0.013* (0.007)	-0.018** (0.008)
ROA	-0.494* (0.286)	-0.170*** (0.064)	-0.063 (0.044)
Total Reserves/Total Assets	-0.044 (0.457)	-0.174*** (0.066)	-0.093* (0.052)
Age	0.038 (0.056)	-0.002 (0.004)	-0.005 (0.004)
ln (Issued Share Capital)	-0.134 (0.195)	0.063*** (0.023)	0.048* (0.025)
Constant	5.646** (2.649)	-0.378 (0.298)	-0.336 (0.316)
Observations	1,595	2,469	2,469
R-squared	0.010	0.156	0.068
Number of Firms	206	293	293
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Clustered SE	YES	YES	YES

*Notes:* This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is the weighted average coupon payments on a firm's issued bonds in column (1); Total Common Share Capital/Total Assets in column (2); and Total Preference Share Capital/Total Assets in column (3). 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. See Appendix Table A2 for variable definitions and sources. Clustered robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

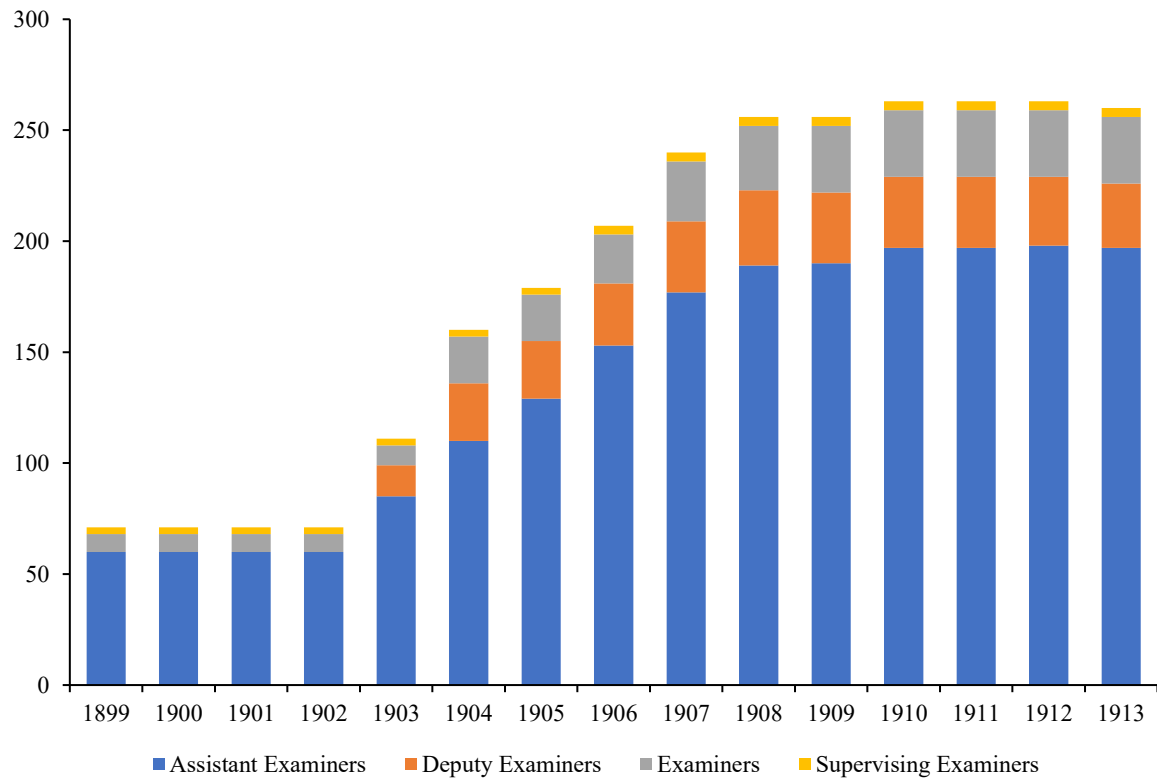
Table 11. Effect of patent examination on firm size

Variable	(1)	(2)	(3)	(4)	(5)
Patenting Firm	-0.041*	-0.042*	-0.037	-0.046*	-0.029*
	(0.022)	(0.023)	(0.025)	(0.026)	(0.015)
Examination Years	0.226***	-0.193	-0.223	-0.185	-0.121
	(0.037)	(0.149)	(0.154)	(0.158)	(0.105)
Patenting x Examination	0.098***	0.103***	0.106***	0.113***	0.067***
	(0.031)	(0.031)	(0.032)	(0.033)	(0.018)
ROA		0.005	0.145	-0.042	0.233*
		(0.212)	(0.166)	(0.204)	(0.120)
Total Reserves/Total Assets		0.202			
		(0.185)			
ln (Total Reserves)			0.038***	0.033***	0.029***
			(0.011)	(0.010)	(0.007)
ln (Retained Earnings)				0.021***	0.013***
				(0.007)	(0.004)
ln (Issued Share Capital)					0.710***
					(0.028)
Age		0.028**	0.029**	0.025**	0.014*
		(0.012)	(0.012)	(0.013)	(0.008)
Constant	13.281***	12.993***	12.648***	12.579***	3.692***
	(0.025)	(0.126)	(0.142)	(0.147)	(0.364)
Observations	2,509	2,471	2,165	2,036	2,035
R-squared	0.173	0.168	0.254	0.272	0.664
Number of Firms	295	293	280	264	264
Year FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES

*Notes:* This table presents results of two-way fixed effects difference-in-differences panel regressions examining the introduction of patent examination on patenting firms' debt financing. The dependent variable is the natural log of the book value of Total Assets. 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. See Appendix Table A2 for variable definitions and sources. Clustered robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

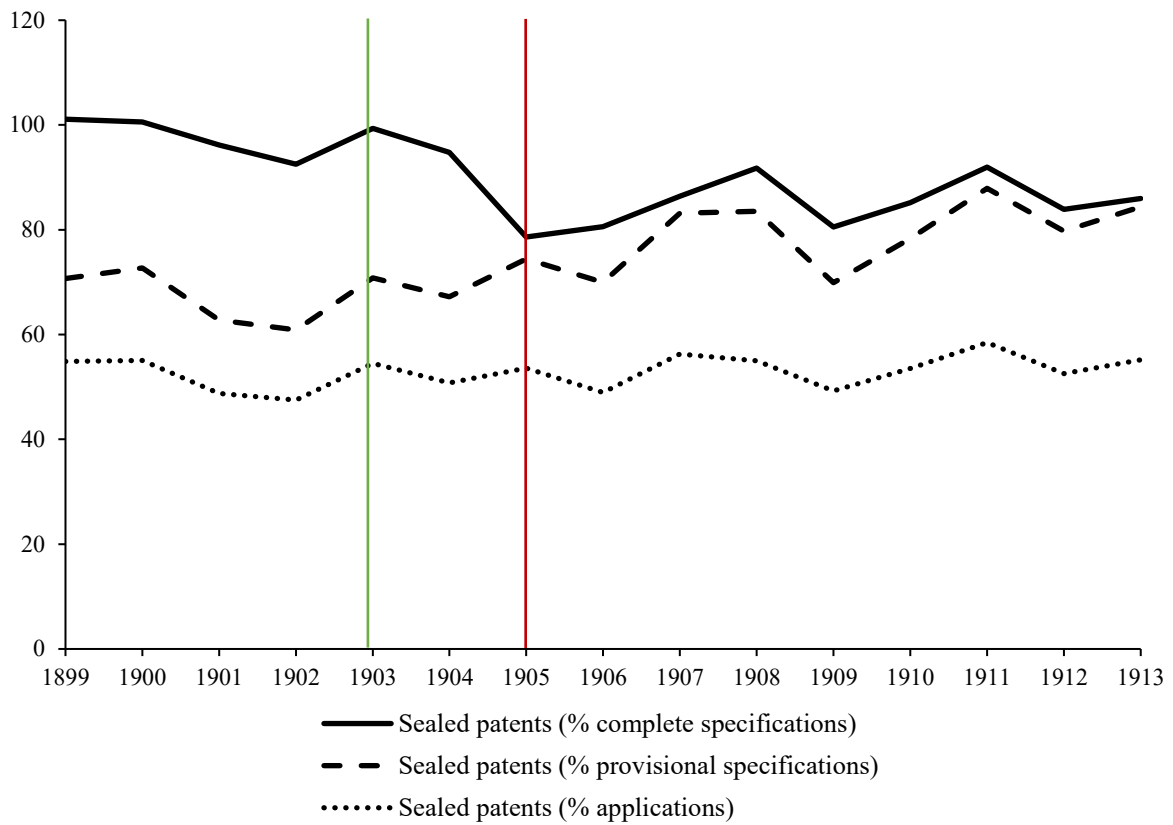
## Figures

Figure 1. Patent examiners employed by the Patent Office, 1899–1913



Sources: Authors' calculations using data published in the *Reports of the Comptroller-General* (1899–1913).

Figure 2. Patenting activity in the UK, 1899–1913

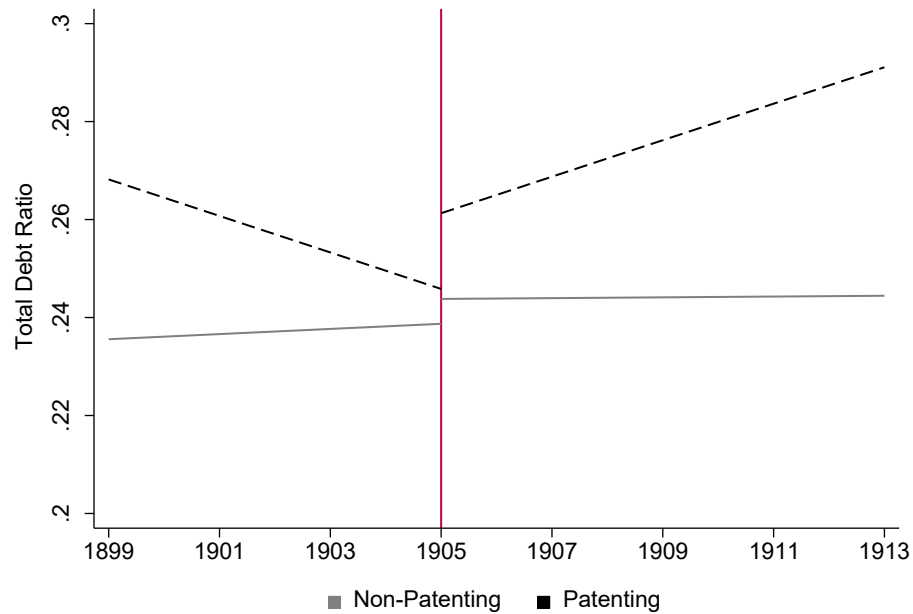


*Notes:* Figure depicts the ratio of patents granted or ‘sealed’ each year against yearly total applications, yearly complete specification filings, and yearly provisional specification filings. The green vertical line indicates the date of Royal Assent of the Patents Act 1902 (18 December 1902); the red vertical line indicates the date from which the Patent Office undertook its first prior art search examinations (1 January 1905).

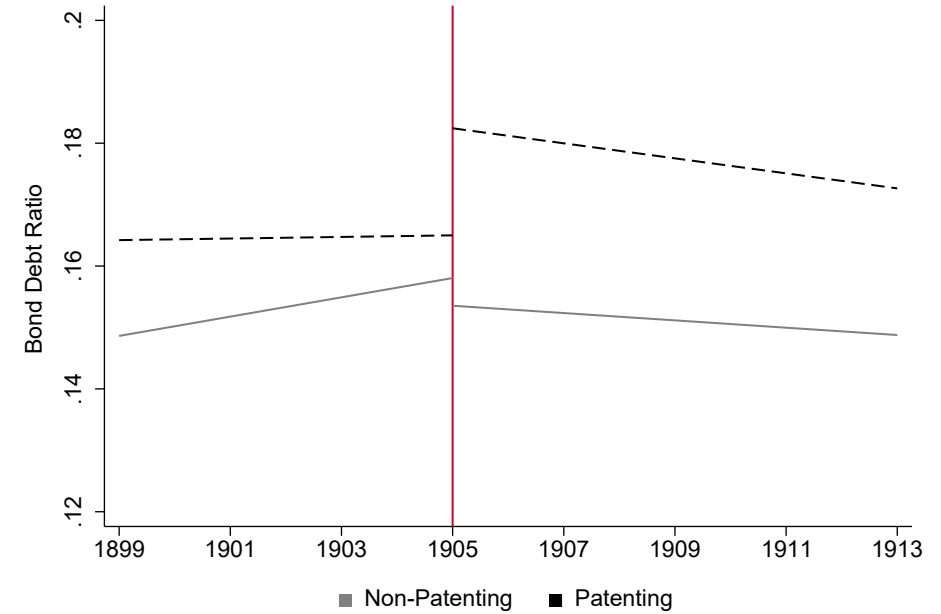
*Sources:* Authors’ calculations using data published in the *Reports of the Comptroller-General* (1899–1913).

Figure 3. Debt/total assets ratio trends for patenting and non-patenting firms, 1899–1913

Panel A. Total debt/total assets



Panel B. Bond debt/total assets



*Notes:* This figure shows the trend of the average level of total debt-to-assets and total bond debt-to-total-assets for patenting and non-patenting firms, before and after patent examination was introduced in 1905.

*Sources:* Authors' calculations using data described in Section 3.

## Appendices

### Appendix A: Additional tables and figures

Table A1. Results of patent examination, 1905–1913

Year	Sealed	Prior art search			Amendments following search		
		Anticipated		Not anticipated	Amended by patentee		Insertion of forced reference
		Wholly	Partly		Without hearing	After decision	
1905	15,369	1,308	8,238	5,283	7,725	1,060	556
1906	16,972	1,111	9,743	6,118	8,440	1,544	553
1907	16,679	938	10,201	5,540	8,674	1,800	424
1908	16,566	865	10,462	5,239	8,931	1,760	310
1909	16,973	1,048	10,552	5,373	10,053	1,029	379
1910	17,082	1,185	10,383	5,514	10,391	747	322
1911	16,724	1,193	10,233	5,298	10,337	679	303
1912	17,407	1,174	10,903	5,830	11,003	650	311
1913	16,708	1,002	10,401	5,305	10,422	593	286

*Notes:* ‘Sealed Patents’ refer to all patents where a complete specification has been granted and the sealing fee paid. ‘Wholly’ anticipated refers to a patent’s claims entirely matching a previous specification. ‘Partly’ anticipated refers to one or several of a patent’s claims matching previous specifications.

*Sources:* Authors’ calculations using data published in the *Reports of the Comptroller-General* (1905–1913).

Table A2. Variable definitions and sources

Variable	Definition	Sources
<i>Patenting Behaviour</i>		
Patenting Firm	=1 in years after a firm has a granted <i>unexamined</i> patent before 1905, and/or a granted <i>examined</i> patent from 1905 onwards, = 0 otherwise (year of accounts)	PATSTAT
Examination Years	=1 if examination regime (1905-1913), = 0 otherwise (1899–1904)	PATSTAT
Patenting x Examination	Interaction of Patenting Firm and Examination Years (the ‘Examination Effect’)	PATSTAT
Anticipation Patenting	=1 in 1903 or 1904 (after examination is announced but before introduction) after a firm has a granted patent, = 0 otherwise (year of accounts)	PATSTAT
Anticipation Years	=1 if 1903 or 1904 (i.e., the years after examination announcement, but before policy implementation)	PATSTAT
Anticipation Effect	Interaction of Anticipation Patenting and Anticipation Years	PATSTAT
<i>Balance Sheet Items</i>		
Total Assets	Book value of total assets	Balance sheets
Issued Share Capital	Book value of total issued shares	Balance sheets
Total Debt	Book value of total debt	Balance sheets
Bond Debt	Book value of corporate bonds (debentures)	Balance sheets
Other Debt	Total debt excluding bond debt	Balance sheets
Bank Debt	Total bank borrowing	Balance sheets
Cash Total	Total cash and cash equivalents	Balance sheets
Trade Credit	Total credit from trade	Balance sheets
Total Reserves	Total held in reserves and funds	Balance sheets
Net Profit	Profit before distribution (after expenses incl. depreciation, interest)	Balance sheets
Retained Earnings	Accumulated net income or loss carried to following year	Balance sheets
<i>Firm Characteristics</i>		
Age	The number of years since incorporation	SEYB
London HQ	=1 if firm is headquartered in London, = 0 otherwise	SEYB
Family Controlled	=1 if family-controlled firm, =0 otherwise (family controlled if at least two listed Directors have the same surname, or the managing Director’s surname is in the Company’s name)	SEYB
Iron	=1 if firm is in the Iron, Coal & Steel Sector, = 0 otherwise	SEYB
<i>Balance Sheet Ratios</i>		
Return on Assets (ROA)	Net profit/total assets	Balance sheets
Return on Equity (ROE)	Net profit/total issued share capital (book value)	Balance sheets
Tobin’s Q	(Book value of debt + book value of preference equity + market value of common equity)/book value of total assets	Balance sheets; SEDOL
Maturity Ratio	Retained earnings/ordinary equity (book value)	Balance sheets; SEDOL
<i>Robustness Variables</i>		
Weighted Average Debt Cost	Weighted average coupon payments on a firm’s issued bonds	Balance sheets
Total Common/Total Assets	Book value of total common shares issued/total assets	Balance sheets
Total Preference/Total Assets	Book value of total preference shares issued/total assets	Balance sheets

Notes: PATSTAT = EPO’s PATSTAT Biblio (Autumn 2016 version); SEYB = Stock Exchange Yearbook; SEDOL = Stock Exchange Daily Official Lists.

Sources: Balance sheets, SEYB and SEDOL are available at the Guildhall Library, London.

Table A3. Test of pre-reform trend differences

Variable	(1) Total Debt/Total Assets	(2) Total Debt/Total Assets
Patenting Firm	0.031 (0.047)	0.065 (0.056)
1900.AccountYear	0.007 (0.021)	0.006 (0.020)
1901.AccountYear	0.009 (0.021)	0.006 (0.021)
1902.AccountYear	0.005 (0.021)	0.004 (0.021)
1903.AccountYear	0.000 (0.020)	0.002 (0.020)
1904.AccountYear	0.006 (0.021)	0.009 (0.020)
Patenting#1900	-0.049 (0.059)	-0.062 (0.071)
Patenting#1901	-0.041 (0.056)	-0.046 (0.067)
Patenting#1902	-0.029 (0.056)	-0.049 (0.065)
Patenting#1903	-0.028 (0.053)	-0.062 (0.063)
Patenting#1904	-0.023 (0.053)	-0.064 (0.062)
Constant	0.234*** (0.016)	0.233*** (0.015)
Observations	917	917
R-squared	0.001	0.002

*Notes:* This table tests for differences in pre-trends for patenting and non-patenting firms, before the introduction of patent examination (1899–1904). The dependent variable is Total Debt/Total Assets. Independent variables include year dummy variables, a dummy variable identifying patenting firms, and year-patenting firm interactions. Column (1) uses the year of patent filing to identify a patenting firm; column (2) uses the year of patent grant to identify a patenting firm. See Appendix Table A2 for variable definitions and sources. Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A4. Pooled analysis

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Total Debt	Total Debt	Bond Debt	Bond Debt	All Non-Bond	All Non-Bond	Bank Debt	Bank Debt	Trade Credit	Trade Credit
Patenting Firm	-0.008 (0.009)	-0.009 (0.009)	-0.017* (0.009)	-0.017* (0.009)	0.009 (0.006)	0.008 (0.006)	0.003* (0.002)	0.003* (0.002)	0.004 (0.005)	0.004 (0.005)
Examination Years	0.029 (0.066)	0.015 (0.067)	0.001 (0.049)	-0.002 (0.051)	0.027 (0.048)	0.017 (0.048)	0.027 (0.017)	0.028 (0.018)	-0.006 (0.042)	-0.018 (0.043)
Patenting x Examination	0.024** (0.012)	0.024** (0.012)	0.031** (0.012)	0.030** (0.013)	-0.007 (0.007)	-0.006 (0.007)	-0.007** (0.003)	-0.007** (0.003)	0.002 (0.006)	0.003 (0.006)
ROA	-0.393*** (0.074)	-0.433*** (0.074)	-0.274*** (0.060)	-0.287*** (0.064)	-0.119** (0.055)	-0.146** (0.057)	-0.069*** (0.022)	-0.067*** (0.025)	-0.037 (0.048)	-0.062 (0.050)
Total Reserves/Total Assets	-0.466*** (0.075)	-0.459*** (0.076)	-0.285*** (0.063)	-0.270*** (0.063)	-0.181*** (0.055)	-0.189*** (0.057)	-0.052* (0.027)	-0.053* (0.028)	-0.135*** (0.040)	-0.143*** (0.041)
Age	-0.000 (0.008)	0.001 (0.008)	0.000 (0.006)	0.001 (0.006)	-0.000 (0.006)	0.001 (0.006)	-0.002 (0.002)	-0.003 (0.002)	0.003 (0.005)	0.004 (0.005)
ln (Issued Share Capital)	-0.084*** (0.022)	-0.091*** (0.022)	-0.065*** (0.023)	-0.070*** (0.024)	-0.019 (0.013)	-0.021 (0.013)	-0.009 (0.007)	-0.008 (0.007)	-0.010 (0.009)	-0.012 (0.010)
Maturity Ratio		0.036 (0.041)		0.020 (0.041)		0.016 (0.025)		-0.006 (0.013)		0.017 (0.022)
London HQ	-0.179 (0.114)	0.282* (0.149)	-0.068 (0.085)	0.206* (0.113)	-0.110 (0.082)	0.077 (0.106)	-0.050* (0.029)	0.042 (0.038)	-0.051 (0.074)	0.047 (0.095)
Family Firm	-0.270 (0.201)	-0.318 (0.205)	-0.218 (0.151)	-0.237 (0.158)	-0.052 (0.145)	-0.081 (0.145)	-0.034 (0.050)	-0.028 (0.052)	-0.035 (0.131)	-0.070 (0.132)
Iron		0.438*** (0.035)		0.264*** (0.028)		0.174*** (0.024)		0.094*** (0.008)		0.082*** (0.022)
Constant	1.526*** (0.277)	1.174*** (0.288)	1.101*** (0.291)	0.907*** (0.302)	0.424*** (0.161)	0.267 (0.173)	0.223** (0.086)	0.120 (0.092)	0.190 (0.119)	0.132 (0.127)
Observations	2,469	2,391	2,469	2,391	2,469	2,391	2,469	2,391	2,469	2,391
R-squared	0.894	0.897	0.922	0.923	0.769	0.768	0.479	0.479	0.785	0.784
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

*Notes:* This table presents results of pooled regressions examining the introduction of patent examination and patenting firms' debt financing. The dependent variable is Total Debt/Total Assets (columns 1 and 2); Bond Debt/Total Assets (columns 3 and 4); Non-Bond Debt/Total Assets (columns 5 and 6); Bank Debt/Total Assets (columns 7 and 8); Trade Credit Debt/Total Assets (columns 9 and 10). 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. 'Anticipation Effect' is an interaction to test any additional anticipatory effect of patenting after the announcement of patent examination legislation, but before its implementation in 1905 (i.e. 1903 and 1904). See Appendix Table A2 for variable definitions and sources. Clustered robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A5. Total debt/total assets analysis after adjusting control sample

Variable	(1) PSM	(2) EB	(3) Never Patent
Patenting Firm	-0.008 (0.008)	-0.008 (0.009)	
Examination Years	0.035 (0.099)	-0.029 (0.161)	0.061 (0.108)
Painting x Examination	0.024** (0.011)	0.025** (0.012)	0.026** (0.012)
ROA	-0.393*** (0.070)	-0.424*** (0.113)	-0.378*** (0.073)
Total Reserves/Total Assets	-0.466*** (0.070)	-0.522*** (0.117)	-0.478*** (0.077)
Age	-0.000 (0.007)	0.006 (0.012)	-0.002 (0.008)
ln (Issued Share Capital)	-0.084*** (0.021)	-0.097*** (0.027)	-0.093*** (0.023)
Constant	1.381*** (0.275)	1.528*** (0.357)	1.510*** (0.302)
Observations	2,469	2,213	2,105
Number of Firm	293	227	215
R-squared	0.143	0.167	0.152
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Clustered SE	YES	YES	YES

*Notes:* This table presents results of two-way fixed-effects difference-in-differences panel regressions examining the introduction of patent examination and patenting firms' debt financing. The regression analysis is conducted on matched control samples derived from: (1) a propensity score matching (PSM) procedure; (2) an entropy balancing (EB) procedure; (3) firms that never patented, neither in the pre- nor post-reform periods. The dependent variable is Total Debt/Total Assets. 'Patenting Firm' is a dummy variable that =1 in years once a firm has a granted *unexamined* patent before 1905, and a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. Control variables for firm profitability, self-financing ability, size and age are included, as are firm and year controls. See Appendix Table A2 for variable definitions and sources. Clustered standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A6. Analysis using alternative firm profitability definition (ROE)

Variable	(1) Total Debt/ Total Assets	(2) Bond Debt/ Total Assets	(3) Other Debt/ Total Assets	(4) Bank Debt/ Total Assets	(5) Trade Credit/ Total Assets
Patenting Firm	-0.009 (0.008)	-0.018** (0.009)	0.009 (0.005)	0.003* (0.002)	0.004 (0.005)
Examination Years	0.031 (0.099)	0.006 (0.074)	0.025 (0.072)	0.038 (0.025)	-0.022 (0.064)
Patenting x Examination	0.025** (0.011)	0.032*** (0.012)	-0.007 (0.006)	-0.007** (0.003)	0.002 (0.005)
ROE	-0.151*** (0.032)	-0.097*** (0.023)	-0.054* (0.027)	-0.034*** (0.012)	-0.015 (0.024)
Total Reserves/Total Assets	-0.458*** (0.070)	-0.278*** (0.059)	-0.180*** (0.051)	-0.051** (0.026)	-0.135*** (0.037)
Age	0.000 (0.008)	0.001 (0.006)	-0.000 (0.005)	-0.002 (0.002)	0.003 (0.005)
ln (Issued Share Capital)	-0.087*** (0.021)	-0.066*** (0.022)	-0.021* (0.012)	-0.009 (0.007)	-0.010 (0.009)
Constant	1.399*** (0.275)	1.024*** (0.286)	0.375** (0.164)	0.160* (0.085)	0.196 (0.121)
Observations	2,469	2,469	2,469	2,469	2,469
R-squared	0.134	0.099	0.049	0.027	0.031
Number of Firms	293	293	293	293	293
Year FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES

*Notes:* This table replicates key results from the paper's main analysis, but substituting Return on Equity ('ROE') for Return of Assets ('ROA'). 'Patenting Firm' is a dummy variable that =1 in years once a firm has obtained a granted *unexamined* patent before 1905, and/or a granted *examined* patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. 'Anticipation Effect' is an interaction to test any additional anticipatory effect of patenting after the announcement of patent examination legislation, but before its implementation in 1905 (i.e., covering 1903 and 1904). See Appendix Table A2 for variable definitions and sources. Clustered robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A7. Analysis using patent filing date rather than grant date

Variable	(1)	(2)	(3)	(4)	(5)
	Total Debt/ Total Assets	Bond Debt/ Total Assets	Other Debt/ Total Assets	Bank Debt/ Total Assets	Trade Credit/ Total Assets
Patenting	-0.011 (0.009)	-0.022** (0.009)	0.012** (0.006)	0.004* (0.002)	0.007 (0.005)
Examination Years	0.038 (0.099)	0.011 (0.074)	0.027 (0.072)	0.038 (0.025)	-0.020 (0.064)
Patenting x Examination	0.026** (0.011)	0.033*** (0.012)	-0.007 (0.006)	-0.004 (0.003)	-0.001 (0.006)
ROA	-0.391*** (0.070)	-0.270*** (0.056)	-0.121** (0.051)	-0.069*** (0.021)	-0.039 (0.045)
Total Reserves/Total Assets	-0.466*** (0.070)	-0.284*** (0.059)	-0.183*** (0.051)	-0.052** (0.025)	-0.136*** (0.037)
Age	-0.000 (0.007)	-0.000 (0.006)	-0.000 (0.005)	-0.002 (0.002)	0.003 (0.005)
ln (Issued Share Capital)	-0.084*** (0.021)	-0.065*** (0.022)	-0.020 (0.012)	-0.009 (0.007)	-0.010 (0.009)
Constant	1.385*** (0.275)	1.022*** (0.280)	0.363** (0.163)	0.154* (0.084)	0.192 (0.121)
Observations	2,469	2,469	2,469	2,469	2,469
R-squared	0.144	0.112	0.050	0.025	0.031
Number of Firms	293	293	293	293	293
Year FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES

*Notes:* This table replicates key results from the paper's main analysis, but using patent filing date rather than grant date in judging whether a firm was affected by the new patent examination regime. 'Patenting Firm' is a dummy variable that =1 in years once a firm has filed a patent before 1905, and/or a filed patent from 1905 onwards. 'Examination Years' is a dummy variable that =1 from 1905 onwards, identifying the new patent examination regime. 'Anticipation Effect' is an interaction to test any additional anticipatory effect of patenting after the announcement of patent examination legislation, but before its implementation in 1905 (i.e., covering 1903 and 1904). See Appendix Table A2 for variable definitions and sources. Clustered robust standard errors (at the firm level) in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A8. Treatment effects from Callaway and Sant’Anna (2021) estimation

Event Time	Effect	Std. Error	z-value	p-value	95% Con. Inter.
<i>Panel A</i>					
Pre-Treatment Average	-0.008	0.015	-0.51	0.613	[-0.038 0.022]
Post-Treatment Average	0.402***	0.112	3.59	0.000	[0.182, 0.621]
<i>Panel B</i>					
Pre-Treatment Average	-0.003	0.018	-0.17	0.868	[-0.038, 0.032]
Post-Treatment Average	0.023**	0.011	2.21	0.027	[0.003, 0.044]

*Notes:* The coefficients represent the estimated average treatment effect on the treated (ATT) for each relative time period on Total Debt / Total Assets using the Callaway and Sant’Anna (2021) difference-in-differences method, which accounts for staggered treatment timing and heterogeneous treatment effects across units and over time. ‘Pre-Treatment Average’ denotes the average effect in the pre-treatment period (before firms have examined patents), while ‘Post-Treatment Average’ denotes the average effect of an examined patent over all post-examined-patent periods. The model in Panel A includes firm fixed effects, year fixed effects, and controls for firm profitability (ROA), liquidity (Total Reserves to Total Assets), age, and size. Panel B also controls for patenting before the introduction of examination. Standard errors are clustered at the firm level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table A9. Summary statistics from placebo simulations

Statistic	Value
Number of simulations	1,000
Mean placebo ‘examined patent’ coefficient ( $\beta$ )	-0.003
Standard deviation of placebo coefficient	0.013
% of significant placebo effects ( $p < 0.05$ )	6.60%
% of significant and positive placebo effects	1.3% (13/1000)

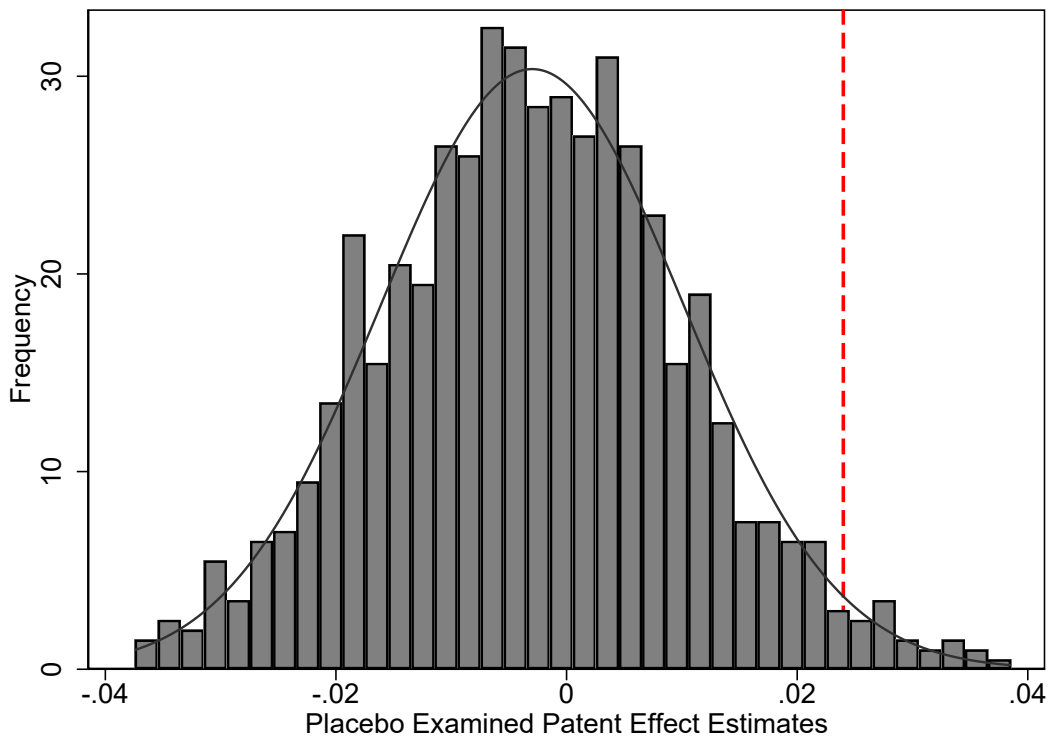
*Notes:* This table summarizes the results from 1,000 placebo simulations designed to assess the robustness of the estimated treatment effect of patent examination on firm leverage. In each iteration, patenting status and patent timing were randomly assigned at the firm level. All placebo regressions replicate the specification of the main difference-in-differences model in Table 6 column 2.

Table A10. Contrast analysis, pre- versus post-reform

Aspect	Pre-Reform (Before 1905)	Post-Reform (After 1905)	Key Insight
Patent Application Process	Patents granted based on simple formalities examination, with low fee.	Applications now subjected to prior art examination, with same low fee.	Increased barriers discouraged low-quality applications.
Role of Patent Examiners	No substantial role in quality control beyond limited legal aspects.	Expert scientists employed as patent examiners to conduct prior art search and provide feedback.	Introduction of examiners institutionalised quality control, improving reputation of patent system.
Patent Application Abandonment Rates	Rare abandonment as there was little scrutiny of patent claims.	Increased abandonment rates after examiners identified prior art conflicts.	Higher abandonment rates due to improved patent screening, ensuring more valuable patents proceeded to grant.
Patent Quality	High number of low-quality patents, creating noise in innovation signals.	Increased quality through screening out of low-value non-novel patents.	Improved average patent quality helped public identify potentially valuable innovations.
Signal to Investors	Weak signal of private value of invention due to lack of quality differentiation.	Stronger signal as examined patents demonstrated higher reliability and potential value.	Examination created stronger link between patents and firm innovation capabilities, boosting investor confidence.
Debt Accessibility for Firms	Patenting firms showed similar debt-to-asset ratios as non-patenting firms.	Patenting firms now achieved higher debt-to-asset ratios, particularly through using bond markets.	Examined patents acted as credible signals of invention quality, improving access to capital markets for innovative firms.

*Notes:* Table summarises key arguments presented in text, contrasting pre- with post-reform patent system along several dimensions.

Figure A1: Distribution of placebo estimates from simulated regressions



*Notes:* This figure presents the distribution of estimated examined patent effects from 1,000 placebo difference-in-differences regressions. In each simulation, firms are randomly assigned a placebo patenting-firm indicator and a random year of patent. The dependent variable in all regressions is the firm's total debt-to-assets ratio. Each regression is structured as the original in Table 6 column 2, including firm fixed effects, year fixed effects, and controls for firm profitability (ROA), liquidity (Total Reserves to Total Assets), age, and size, with standard errors clustered at the firm level. The vertical red dashed line marks the estimated treatment effect from the actual difference-in-differences in Table 6 column 2 (0.024), which represents the increase in leverage following an examined patent grant.

## **Appendix B: Contemporary press evidence on the corporate value of patents**

This section collates some contemporary press evidence published in *The Times* (of London) and *The Financial Times* that explicitly highlight the value of patents to firms and investors, as well as their role in securing bondholders, during the period 1899–1913. The evidence includes company prospectuses, partnership and investment advertisements, AGM report, and court cases. These materials support the idea that patents functioned as a signal of value for firms, particularly when raising capital, and that the introduction of patent examination strengthened the credibility of that signal.

Table B1 reports examples from company prospectuses published when raising capital from investors. In some cases the prospectus relates to company IPOs in which the stated rationale for incorporation was to acquire and commercialise existing patent rights. This implies that these firms' entire value proposition was derived from the patent rights and their underlying innovation. In other cases, the stated purpose was to raise capital to expand the company's patent portfolio. Notably, some companies explicitly referenced the value of patent examination, and the use of patent rights as collateral for debtholders.

Many prospectuses sought to highlight the quality of their patented inventions using testimony from patent experts, typically either a Chartered Patent Agent or eminent Patent Counsel. This strategy leveraged the reputational capital of individuals with legal and technical expertise to enhance investor perception of the value of the company's patents. A common approach involved including a statement from a patent agency, confirming that a prior search of British patent specifications had been conducted to establish novelty. This was typically followed by an opinion from a named patent counsel assessing the likely validity of the patent if legally challenged.

For example, the *Pedlar Brake and Two-Speed Gear Company* reported that it incorporated to acquire British and foreign patent rights related to bicycle technology. To demonstrate the strength of its patents, the firm hired a patent agency, *Messrs Rayner and Co.*, to conduct an exhaustive search of prior British patent specifications, and Mr J. Fletcher Moulton an MP and recognised authority on patent law, for legal opinion. The findings were then reported in the prospectus:

'Dear Sir,- In accordance with your instructions we have made a search in the Records of the British Patent Office on the subject and claims of the complete specification of the above application, the search extending from the date of the application back to and including the year 1877 under the headings of Velocipedes: driving mechanism; Motor Road Vehicles: driving, gear, foot, hand or power. During the course of the search nearly 4,000 specifications were examined, and as the result we are pleased to be able to inform you that we consider the apparatus of Mr. Sturgess to possess ample novelty to support

a good and valid Patent. None of the previous patents show such a combination of advantages as Mr. Sturgess's hub contains and give so complete a control over the wheel.'

*Rayner & Co.* (28 September 1904)

'I am of opinion that with the suggested amendments, which have been evidently drawn with great care, the Patents submitted to me, namely, Nos. 1127 of 1900, 24965 of 1902, and 21640 of 1903, will be good and valid, and will not be anticipated by any of the prior specifications sent with the case.'

*J. Fletcher Moulton, Temple, E.C.* (21 December 1904)

In the example of the 1900 prospectus of *The Lanston Monotype Corporation*, the firm explicitly describes its patent right as a form of collateral to prospective bondholders:

'The Debenture Stock will be secured to the Trustees for the Debenture Stock Holders by a First Mortgage on the freehold and leasehold properties and the Letters Patent, and a floating charge on the undertaking and general assets of the Corporation.'

*The Lanston Monotype Corporation* (21 December 1900)

Notably, in a later (post 1905) prospectus, the *British Coalite Company* explicitly referenced that the validity of their patent rights was confirmed by the new British patent examination system:

'Exhaustive searches as to previous patents have been made in the British, German, French, and United States Patent Records, by Messrs Edward Evans and Co., of Chancery Lane, W.C., which have been confirmed by the official examinations as to novelty made in the United Kingdom, Germany, and the United States.'

*The British Coalite Company* (18 June 1907)

Patent rights were also used to attract investors in the form of small-scale start-up capital or business partners. Notices frequently appeared in *The Times* newspaper's "Partnerships, Investments, &c." column. For example, an advertisement dated 12 November 1907 states: 'ENGINEERING FIRM, protected by several patents, REQUIRES further WORKING CAPITAL, privately or syndicate. Suit naval or military office, or millowner'. Another dated 11 July 1907, requests: 'FINANCIER, with £1,000 WANTED, to place a very successful patent on a steam plant. One who would not object to a company being formed'. Notably, these advertisements disclose little about the patents themselves beyond asserting ownership. Yet, this minimal disclosure appears to have been deemed sufficient to attract interested investors, suggesting that patent ownership alone was believed to serve as a credible signal of value to potential investors.

At the 1899 AGM of the British Motor Company, prior to the introduction of patent examination, both the strategic value of patents and the difficulty of proving their validity were emphasised. It was reported that patents would allow the company to "cut the ground from

beneath the feet of its rivals”, and that legal challenges, necessary to prove the validity of their patents, had “added immensely to their value”, as every victory “sent the price up”. The company saw active legal enforcement to patent infringement as a necessary defence against those who would “steal the shareholder’s property” (*The Financial Times*, 3 January 1899, p. 5).

The role of patents as valuable firm assets is also evident in legal proceedings following the liquidation of failed companies, particularly in their use as security for bondholders. In the case of Celladema (Limited), the original purchase price of the company reportedly considered that their patent was worth £5,000 (*The Times*, 23 February 1899, p. 14). Following the winding-up order of the London and Birmingham Brass Foundry Ltd, initiated by debenture holders, it was noted that the company was formed specifically to acquire another firm’s patent rights, for which £40,000 had been paid (*The Financial Times*, 3 January 1899, p. 3). In another example, the assets of Fuller, Horsey, Sons and Cassell were listed for auction by order of the Court, instigated by debenture holders. The assets included the company’s letters patent and patented bag machines (*The Times*, 17 June 1905, p. 19).

Table B1. Examples of prospectuses published in *The Times* mentioning patents

Company	Year	Capital Issued	Reason for Raising Capital
Nernst Electric Light*	1899	Shares	Acquisition of patents
The British Charrier Wood Carving Company*	1899	Shares	Acquisition of patents
Lanston Monotype Corporation*	1900	Debentures	Expansion of capital stock
Bayliss, Jones, and Bayliss*	1901	Debentures	Acquisition of land and patents
The Linotype Company	1901	Shares and Debentures	Expansion of capital stock
The Projectile Company (1902)*	1902	Shares and Debentures	Working capital
The Peldar Brake and Two-Speed Gear Company	1905	Shares	Working capital
The British Coalite Company	1907	Shares	Working capital
The Molassine Company*	1907	Shares	Working capital
Vickers, Sons &Maxin, Limited*	1908	Shares and Debentures	Working capital
Aron Electricity Meter*	1911	Debentures	Expansion of capital stock

Notes: \* indicates companies in our dataset