Bankruptcy Codes and Innovation[1]

Viral V. Acharya
London Business School & CEPR
vacharya@london.edu

Krishnamurthy Subramanian
Emory University
ksubramanian@bus.emory.edu

April 27, 2007

[1]We are grateful to Raghu Sundaram for numerous discussions since the early stage of the project, and to seminar participants at Emory University, the Federal Reserve Board of Governors, Stanford and U.C. Berkeley. Rong Leng deserves our special thanks for her excellent research assistance. All errors remain our own. A part of this paper was completed while Viral Acharya was visiting Stanford GSB. Contact author: Viral V. Acharya, London Business School, Regent's Park, London - NW1 4SA, UK. Tel: +44 (0)20 7000 8255, Fax: +44 (0)20 7000 8201, e-mail: vacharya@london.edu, Web: http://www.london.edu/faculty/vacharya

Abstract

Bankruptcy Codes and Innovation

Do legal institutions governing financial contracts affect the nature of real investments in the economy? We develop a simple model and provide evidence that the answer to this question is yes. We consider a levered firm's choice of investment between innovative and conservative technologies, on the one hand, and of financing between debt and equity, on the other. Bankruptcy code plays a central role in these choices by determining whether the firm is continued or liquidated in case of financial distress. When the code is creditor-friendly, excessive liquidations cause the firm to shy away from innovation. In contrast, by promoting continuation upon failure, a debtor-friendly code induces greater innovation. This effect remains robust when the firm attempts to sustain innovation by reducing its debt under creditor-friendly codes.

Employing patents as a proxy for innovation, we find support for the real as well as the financial implications of the model: (1) In countries with weaker creditor rights, technologically innovative industries create disproportionately more patents and generate disproportionately more citations to these patents relative to other industries; (2) This difference of difference result is further confirmed by within-country analysis that exploits time-series changes in creditor rights, suggesting a causal effect of bankruptcy codes on innovation; (3) When creditor rights are stronger, innovative industries employ relatively less leverage compared to other industries; and (4) In countries with weaker creditor rights, technologically innovative industries grow disproportionately faster compared to other industries. Finally, while overall financial development fosters innovation, stronger creditor rights weaken this effect, especially for highly innovative industries.

JEL: G3, K2, O3, O4, O5.

Keywords: Creditor rights, R&D, Technological change, Law and finance, Entrepreneurship, Growth, Financial development.

1 Introduction

Existing empirical evidence indicates that legal institutions of an economy affect its financial organization and economic growth: specifically, the nature of external financing of enterprises (La Porta, Lopez-de-Silanes, Shleifer and Vishny, 1997, 1998), the ownership structure of firms (La Porta, Lopez-de-Silanes and Shleifer, 1999), the mix between market- and bank-dominated finance (Allen and Gale, 2000), and economic growth through the provision of financial access to firms (King and Levine, 1993, Rajan and Zingales, 1998). Less well understood is whether legal institutions that govern financial contracts affect the nature of real investments in an economy.

In this paper, we focus on one specific aspect of this overarching theme: Does the nature of bankruptcy code affect the extent of innovation in an economy? In our analysis, the bankruptcy code governs whether control rights remain with the equityholders or are transferred to creditors when the firm encounters financial distress. We develop a simple model and provide empirical evidence to show that the creditor- or debtor-friendliness of bankruptcy code affects a levered firm's incentive to innovate by determining if the decision to continue/liquidate the firm in the case of financial distress favors the firm's equityholders or its creditors. Since innovation is essential to sustain high levels of growth in an economy (see the pioneering work on endogenous growth theory of Romer, 1990, Grossman and Helpman, 1991, and Aghion and Howitt, 1992), our results have important consequences for policies aimed at promoting development and growth.[1]

We model a firm's choice between innovative and conservative technologies as a two-armed bandit problem.[2] The "explore" arm has higher value ex ante than the "exploit" arm, but exploration is risky. Exploration reveals at an interim date the quality of the innovation. Given the information revealed at the interim date, switching to the exploit strategy is optimal if (and only if) the news is bad. The firm finances its investment in either technology using debt and equity. As in the static trade-off theory, debt provides the benefit of tax shields. However, at the interim date, the firm may default on its debt payments. This entails deadweight costs of bankruptcy due to inefficient continuation or liquidation at the interim date. We model these deadweight costs as a function of the investment strategy followed by the firm (innovative or conservative), its capital structure (the debt-equity mix) and the bankruptcy code in place (creditor-friendly or debtor-friendly). The firm chooses simultaneously the nature of its real activity and its financing mix.

To fix ideas, consider two polar opposites of the bankruptcy code: First, the debtor-friendly code where equityholders retain all the control rights in bankruptcy; and, second, the creditor-friendly code where all control rights are transferred to a firm's creditors. The non-linearity of creditors' (and equityholders') cash flow claims gives rise to the following effect: under a creditor-friendly code, the innovative technology may be inefficiently liquidated, whereas under a debtor-friendly code, it may be inefficiently continued.[3] While this trade-off arises for the conservative strategy too, greater risk inherent in the innovative strategy accentuates the deadweight costs arising from liquidation under the creditor-friendly code but mitigates the deadweight costs from continuation

[1] See Figure 1 for the positive correlation between countries' GNP per capita and their overall innovation intensity as measured by the total number of patents, citations to these patents, the number of patenting firms, and the average number of patents. Note that GNP per capita of around USD 9000-10000 represents the widely accepted cutoff point for developed versus under-developed economies.

[2] See Sundaram (2003) for a theoretical survey of bandit problems with applications to economics.

[3] Starting with Gertner and Scharfstein (1991), such a tradeoff has been at the center of a large body of finance literature that focuses on the efficiency of bankruptcy mechanisms and their optimal design.

under the debtor-friendly code. Thus, for a given financing mix, a creditor-friendly code discourages risk-taking and innovation relative to a debtor-friendly code. In fact, the inefficient continuation ex post under the debtor-friendly code can be efficient from the standpoint of ex-ante risk-taking.

Interestingly, since firms in our model also choose their financing mix, the optimal financing of an innovative strategy involves lower debt under creditor-friendly code than under debtor-friendly code. That is, in order to pursue the efficient real activity under the creditor-friendly code (which is to innovate in our model), the firm lowers its debt. This, however, comes at a cost to the firm in form of lower tax-shields. Thus, when the code becomes more creditor-friendly, the value of an optimally financed innovative firm reduces while that of an optimally financed conservative firm increases.

The empirical implication of this result can be understood using an example. Consider two industries: Biotechnology and Textiles & Apparel. Firms in the Biotechnology sector have a higher propensity to innovate than firms in the Apparel industry. Given this difference, the above result implies that the difference in innovation between Biotechnology and Apparel would be greater in the United States than in Germany since the rights provided to creditors in bankruptcy are weaker in the United States than in Germany.

To summarize, our theory argues that the nature of bankruptcy codes alters not only the financing mix of the firm but also the nature of its real activity. We provide empirical evidence supporting this implication by examining the intensity of patent creation and patent citations in industry-level, cross-country analysis (difference-in-difference approach), as well as around within-country code changes in the accordance of control rights to creditors (triple difference approach). We use patents issued by the USPTO to US and foreign firms from 1978 to 2002, and citations to these patents, as constructed by Hall, Jaffe and Trajtenberg (2001). The "industry" level classification we employ pertains to the patent sub-classes in this data. We measure innovation intensity for an industry by the median or mean number of patents applied for (and subsequently granted) in a given year in that industry, and by the median or mean number of (all subsequent) citations to these patents.[4] Finally, the information on country-level creditor rights index (a score between 0 and 4) and its within-country time-series change is from Djankov, McLiesh and Shleifer (2005).

Employing patents filed with the USPTO alleviates concerns that may arise when using patents filed in different countries due to differences in protection provided to patents as also the heterogeneity in the patent systems. However, using patents filed with the USPTO introduces potential biases since it is likely that foreign firms file patents with the USPTO because they need to sell their products in the US. In this case, it is likely that foreign firms in an innovation intensive industry such as Biotechnology would file more patents with the USPTO than their counterparts in industries such as Textiles and Apparel. However, since the US had the weakest creditor rights among all countries during our sample period, this bias works against us finding that the difference in patents between Biotechnology and Apparel decreases as creditor rights become stronger.

Our empirical identification follows closely the results from our model. Specifically, we follow the methodology of Rajan and Zingales (1998) and rank patent sub-classes by their patenting intensity in the US. As Cohen, Nelson and Walsh (1996) find in their survey of patenting across various US industries, the propensity to patent is largely driven by technological characteristics of an

[4] While the number of patents capture better the extent of innovative activity, subsequent citations to these patents proxy the impact and quality of the innovation (as in academic settings). Citations help control for country-level differences in the number of patents due to differences in the number and size of firms.

industry. Since the US has had the weakest creditor rights, the best financial markets necessary to fund financially constrained high-growth sectors (Rajan and Zingales, 1998), and the most vibrant research environment, we can make the reasonable assumption that the US ranking best reflects the technological propensity of an industry to innovate.[5]

We first test in the pooled cross-section whether a higher creditor rights index for a country leads to relatively lower generation of patents and citations in industries that have a higher propensity to innovate. We control for the legal origin of a country and various sources of unobserved heterogeneity by including fixed effects at the level of country, 2-digit SIC industry, country interacted with 2-digit SIC, and the application year of the patent. We find the coefficient interaction between propensity to innovate and creditor rights to be uniformly negative and significant, especially when there is no automatic stay on secured creditor claims (greater likelihood of inefficient liquidations) and the incumbent management does not manage in reorganization (greater disincentive to undertake risk ex ante). The economic magnitude of this interaction effect is quite significant too. The strength of this effect is illustrated in Figure 2 which plots, across time, the ratio of number of patents and number of citations for four innovation intensive industries (Computer Pheripherals, Information Storage, Surgery and Medical Instruments, and Biotechnology) relative to a benchmark less innovative industry (Apparel & Textile) for the US and for Germany. In each case, the ratio for the US is substantially higher than that for Germany, often by a factor greater than five-fold with the factor increasing in most cases over time right from 1978 (the beginning of our data and, in fact, the year the US passed the Bankruptcy Reform Act making its code even more debtor-friendly).

In the *strongest piece of evidence* supporting our theory, we consider this interaction effect for the "treatment" sample of countries where creditor rights underwent a change during our sample period, and the "control" sample of other countries. This time-series test has a number of attractive features: First, it is not subject to the omitted-variables bias often raised as an objection to cross-country regression results (our difference of difference approach notwithstanding); second, it removes the onus on the empiricist in terms of having a benchmark such as the US in cross-country tests (which some might argue has had a rather special twentieth century, and especially the latter half, with regard to innovation); and, finally, it provides point estimates on the effect of bankruptcy codes on innovation that are derived from experiments of greatest relevance to policies concerned with promoting innovation.

Consistent with our cross-country findings, we find that the effect of an increase in creditor rights index in a country is to disproportionately lower the generation of patents and citations in industries that have a higher propensity to innovate. For our control group of countries which experience no change in creditor rights, a more innovative industry has 3.5% more patents in a year than the adjacent less innovative one. In contrast, in the treatment group of countries that underwent an increase in creditor rights, this difference in innovation fell to 1.1%, while in countries where creditor rights decreased, this difference in innovation increased to 5.9%. Thus, an increase

[5] In robustness checks, we verify that our results are not sensitive to whether we use contemporaneous US innovation intensity or its lagged values. We also demonstrate robustness to employing the rank ordering itself (rather than the ranking characteristic) and employing industry partitions based on the rank ordering. Furthermore, in a given year, the rank ordering of industries is highly correlated across countries, so that the specific choice of the US for ranking is also not critical to our results. For example, we find our results to be unchanged if we employ the rankings using patents issued to German firms.

in creditor rights made the cross-country difference in the intensity of innovation one-third, while a decrease almost doubled this difference.[6]

Having confirmed the real implications of our model, we examine next the financial implications. Due to limits on data availability, we focus on the G-7 countries and study the relationship between leverage and creditor rights. We find that when creditor rights are stronger, innovative industries take on relatively less leverage compared to other industries. This finding stays robust to different measures of leverage (book, market, inclusive of all non-equity liabilities, and net of cash and cash equivalents). Thus, as predicted by our model, firms in innovative industries do appear to unwind the effect of stronger creditor rights. They do so by undertaking smaller quantities of debt and keeping more cash reserves in order to pursue more innovative projects.

Finally, we ask the question suggested by the endogenous growth literature: how does the differential impact of bankruptcy code on innovative versus non-innovative industries impact their growth rates? In regressions using the growth rates for each ISIC industry in a country, we find the coefficient of the interaction between creditor rights and patenting intensity to be strongly negative. This effect is economically large and is robust to including the Rajan and Zingales (1998) effects of financial development and its interaction with external financial dependence. For a creditor-rights index of one (e.g., the US), the difference in the continuously compounded growth rate over the period 1978-1992 for two adjacently ranked ISIC industries is 3.6%. In contrast, for a creditor-rights index of three (e.g., Germany), this difference is 0.6%. Thus, the difference in growth rates between adjacent industries magnifies by a factor of six as we move from creditor rights index of three to one. In fact, the pattern of growth reverses when the creditor rights index is four (e.g. Hong Kong), with the *less innovative industry* growing at 0.9% more than the more innovative industry.

These results seem to suggest that legal institutions governing financial contracts, in our case bankruptcy codes, have a substantial effect on the nature of real activity in the economy, particularly on the extent of innovative pursuits by firms. They lead to the natural conclusion that the high level of entrepreneurship and innovation in the United States, especially in inherently innovative industries such as Information Technology and Biotechnology, when compared to the developed countries of Europe has been caused (at least in part) by the relatively friendly stance of bankruptcy system in the US to management failures and financial distress.

The paper proceeds as follows. Section 2 describes the related literature. Sections 3 and 4 present the model and its analysis. Section 5 provides empirical evidence supporting the model's implications. Section 6 examines the robustness of our results, specifically examining if country level omitted variables such as the level of financial development proxy for the effect of creditor rights, and if our results are robust to alternative methods of ranking industries for their innovation intensity. Appendix 1 contains the proofs.

[6] We examine empirically the effect of reverse causality in these results and allay such concerns. Also, based on existing studies of what caused the creditor rights to change, we argue later that in case of some countries, the change occurred for exogenous reasons (e.g., to promote employment or protect domestic industries), in others the change occurred precisely to promote innovation and give managers-entrepreneurs a fresh start in default, whereas in others the change was part of an overall package of reforms designed to stimulate growth following recessions.

2 Related Literature

As a broad research enquiry, our work is close to the literature on endogenous growth pioneered by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992). The endogenous growth theory posits that investment in R&D and human capital is the central source of technical progress and an essential ingredient of growth. This theory stresses the need for government and private sector institutions and markets which nurture competition and innovation, provide incentives for individuals to be inventive, and have positive externalities and spill-over effects that can permanently raise a country's long-run growth rate. By developing a model and providing empirical evidence to highlight the role of bankruptcy codes in encouraging innovation, our paper isolates an important legal institution that can affect country's growth. In particular, an important policy implication of our paper is that in countries that have well developed financial systems, empowering creditors in bankruptcy discourages innovative pursuits and may ultimately be detrimental to the country's growth.

Next, we discuss literature that is closer to our goal of linking bankruptcy codes and financing to innovation. Manso (2005) also considers a two-armed bandit problem to study the optimal compensation scheme that motivates exploration. He shows theoretically that the optimal scheme exhibits substantial tolerance (or even reward) for failure and reward for long-term success. Moreover, even though the principal can terminate the agent, inefficient continuation may be optimal to motivate exploration, since the threat of termination may prevent the agent from exploring new untested approaches. He discusses in the paper how debtor-friendly bankruptcy codes could be considered as a way of motivating innovation.[7] Our paper differs from Manso's along two important dimensions: First, by overlaying on the two-armed bandit problem a firm's optimal financing choice, we show that the link between bankruptcy codes and innovation is robust to the firm's attempt to unwind the effect of bankruptcy codes by altering its financing mix; second, we provide empirical test of the link between debtor- or creditor-friendliness of the code and the extent of innovation in the economy. To our knowledge, ours is the first paper to establish this empirical link in cross-country data.

In another related paper, Landier (2006) considers a setting with endogenous cost of entrepreneurial failure and shows that there might be multiple equilibria, one that fosters experimentation and one that promotes conservatism. He considers an extension where bankruptcy codes are either creditor-friendly or debtor-friendly, and shows that the bankruptcy code can resolve the multiplicity of equilibria, making countries with debtor-friendly codes more suitable for entrepreneurship and innovation. However, as in Manso (2005), the financing structure of firms is exogenous in his model.

In contrast to these papers, Acharya, Sundaram and John (2004) and Acharya, Leng and Sundaram (2006) focus on the effect of bankruptcy code on the leverage choice of firms, but take the real technology of the firm as given. Their theoretical results and empirical tests also imply a difference of difference relationship wherein firms with higher anticipated liquidation costs undertake greater debt in debtor-friendly bankruptcy regimes than in creditor-friendly ones. Our

[7] Note that the point that violations of absolute-priority rule, as witnessed under debtor-friendly codes, can lead to greater undertaking of risk has been made before, e.g., see Bebchuk (2002). Bebchuk however focuses on the ex-post inefficiency of such risk-taking, whereas our paper and Manso (2005) argue that this may be efficient from the standpoint of ex-ante risk-taking.

theory implies that such a relationship should also exist when firms or industries are ranked by their technological propensity to innovate, an implication that has not yet been tested empirically. Importantly, our theory also implies that the cost of unwinding the bankruptcy code through a change in the financing mix may be too costly for some firms and they may instead switch the very mix of their real activities. Other firms that derive significant value from innovation would choose to fund their investments entirely through equity since the loss in benefits from switching to the conservative strategy outweigh the loss in net benefits from debt financing. This phenomenon would be particularly acute in creditor-friendly codes. At the margin, creditor-friendliness of bankruptcy codes may not only result in lower (or no) debt for innovative industries, but also lead to lower innovative activity. Providing evidence for this latter effect is the key contribution of our paper.

On the empirical front, our paper is clearly related to the literature on law and finance (cited in the introductory paragraph). The closest empirical piece however is provided by Fan and White (2003) who examine how changes in the personal bankruptcy law in various U.S. states (after the 1978 Act) affected entrepreneurship. In bankruptcy, the owner-entrepreneur retains assets up to the exemption level but not beyond. They find that the probability of households owning businesses is 35 percent higher if they live in states with unlimited rather than low exemptions. This lends additional micro-level empirical support to the theory. In contrast, our empirical work provides evidence that corporate bankruptcy codes affect the innovative pursuits of corporations. As Baumol (2001) documents that more than 80% of innovation in the US is done by publicly traded corporations, our empirical results are potentially more important for aggregate innovation in a country. In examining the effect of legal and financial variables on growth rates across different industries, our paper relates to Rajan and Zingales (1998). They examine how the extent of dependence of an industry on external finance differentially impacts industries' growth rates depending upon a countries financial development. Even after accounting for the effects in Rajan and Zingales (1998), we find that a country's bankruptcy code and its interaction with the innovation intensity of an industry significantly affects an industry's growth rate.

Acharya, Amihud and Litov (2007) have a similar empirical objective as ours but focus instead on measures of conservatism, such as, the propensity of firms in the country to engage in diversifying mergers and their operating risk. They find that countries with stronger creditor rights exhibit greater conservatism and that the dominant effect is from the creditor right corresponding to whether the management stays in place during bankruptcy or not. Like Fan and White's evidence, this paper's evidence also offers a complementary test of our overall hypothesis.

In less directly related work, Chhava and Roberts (2006) and Nini, Smith and Sufi (2006) consider the effect on firm-level investments of creditor rights, captured in the form of covenants and capital expenditure restrictions that are explicitly contained in debt contracts. They document restrictive effects of debt contracts on investments. While these studies are limited to the U.S. data, our empirical work relies on the assumption that stronger creditor rights in countries such as the UK and Germany lead to greater restrictions on continuation investments than in countries with weaker creditor rights such as the U.S. An important difference also lies in our focus on the ex-ante effects of creditor rights rather than on the ex-post ones, that is, once covenants bind or distress has occurred.

Finally, our reliance on patent-based measures for intensity of innovation finds parallel in a large body of literature that we discuss in greater detail in the empirical section of the paper.

3 Model

We model a firm's investment and financing decisions simultaneously to examine how the investment decision is affected by the way it is financed, and by the bankruptcy regime under which it operates.

Figure 3 summarizes the time line and events in the model. There are three dates, $t = 0, 1, 2$. At date 0, the firm chooses its Investment Strategy. Specifically, the firm needs to decide whether it should innovate or it should continue to follow its tried-and-tested strategies. Each of these strategies generates risky cash flows and is financed using debt and equity whose optimal mix is also determined by the firm at date 0. The debt matures at date 1. The investment strategies produce two streams of cash flows, one in the short term (which coincides with date 1) and one in the far horizon (date 2).

The firm's short-term cash flow serves two purposes. First, it generates the cash that can be used to service its debt. If the cash flow generated is insufficient to meet debt obligations, the firm is in financial distress, and the bankruptcy code in place determines whether control rights are bestowed upon equityholders or creditors. In particular, the bankruptcy code regulates whether the equityholders or the creditors decide whether to liquidate the firm or to continue it. If the decision is made to continue the firm, then the decision maker also has to decide whether to switch the investment strategy or to continue with the earlier one. If the firm is continued at date 1, then the long-term cash flows from the investment strategy chosen at date 1 are realized at date 2.

Second, the firm's short-term cash flow provides important information about future cash flows and liquidation values that may be expected from the project. As described below, the information about future cash flows will be especially relevant when the firm adopts the innovative strategy. Finally, all agents in the model are risk-neutral and the risk-free rate of interest is zero.

3.1 Investment Strategy and Work Methods

There are two possible strategies that the firm can follow: the old work method (called the 'Exploit' strategy) is tried and tested and therefore involves minimal risk of bad cash flows at date 1. Instead, the firm could experiment with a new work method (called the 'Explore' strategy). The advantage of the Explore strategy is the following. If it is tried at date 0, and is successful, then the long-term cash flows of the firm are higher than under the Exploit strategy. However, the Explore strategy has a greater likelihood of producing a low cash flow at date 1. We denote the Exploit and Explore strategies by 1 and 2, respectively, in some of our notation to follow.

3.2 Cash Flows

We denote the date-1 cash flow by $\widetilde{x}$ and the date-2 cash flow by $\widetilde{y}$.

The distribution of the first-period cash flow $\widetilde{x}_i$ depends upon the strategy i implemented at date 0. If the Explore strategy is followed ($i = 2$), then $\widetilde{x}_2$ is distributed uniformly $U(0, 1)$ while if the Exploit strategy is followed ($i = 1$), then $\widetilde{x}_1$ follows the distribution $U(\alpha, 1 + \alpha)$ where $0 < \alpha < 1$. This captures the fact that the Explore strategy has lower expected cash flow at date 1.

The second-period cash flow $\widetilde{y}_j$ depends upon the strategy j that is implemented at date 1 and also the date-1 cash flow.

If the Exploit strategy is implemented at date 1, then the date 2 cash flow is equal to the realized date-1 cash flow with probability p and is zero with probability $(1-p)$. Thus, in this case, the date-1 cash flow does not provide any additional information about the high cash flow at date 2:

$$\widetilde{y}_1 = \begin{cases} x_1 & \text{with probability} \quad p \\ 0 & \text{with probability} \quad 1-p \end{cases} \tag{1}$$

The date-2 cash flow from the Explore strategy depends upon the signal provided by the date-1 cash flow. In particular, if the Exploit strategy ($i = 1$) was implemented at date 0, then the date-1 cash flow is completely *uninformative* about the likelihood of the high cash flow using the Explore strategy. In contrast, if the Explore strategy was implemented at date 0, then the date-1 cash flow provides important information about the probability of high cash flow. If the date-1 cash flow is greater than expected, then this indicates that the Explore strategy is likely to be successful. In this case, the likelihood of the high cash flow at date 2 increases substantially. If, in contrast, the date-1 cash flow is lower than expected, then this indicates that the Explore strategy is likely to fail. In this case, the likelihood of the high cash flow at date 2 decreases substantially:

$$\begin{aligned} \widetilde{y}_2 | \, (\widetilde{x}_2 \geq 0.5) &= \begin{cases} \gamma x_2 & \text{with probability} \quad q_G \\ 0 & \text{with probability} \quad (1-q_G) \end{cases} \\ \widetilde{y}_2 | \, (\widetilde{x}_2 < 0.5) &= \begin{cases} \gamma x_2 & \text{with probability} \quad q_B \\ 0 & \text{with probability} \quad (1-q_B) \end{cases} \end{aligned} \tag{2}$$

where

$$\gamma > 1 \text{ and } q_B < \gamma q_B < p < q_G < \gamma q_G \; . \tag{3}$$

Thus, the probability of a high cash flow using the Explore strategy increases significantly when the signal is good while it decreases considerably after a bad signal ($q_B < p < q_G$). Further, after a good signal, the expected date-2 cash flow from the Explore strategy is greater than the expected cash flow from the Exploit strategy ($p < \gamma q_G$). In contrast, after a bad signal, the expected date-2 cash flow from the Explore strategy is lower than the expected cash flow from the Exploit strategy ($\gamma q_B < p$).

3.3 Liquidation Values

The liquidation value that can be realized at date 1 is a function of the state of the world as also the strategy that was implemented at date 0. If strategy i was implemented at date 0, then the uncertain liquidation value is distributed as follows:

$$\widetilde{L} = \begin{cases} \bar{l} x_i & \text{with probability} \quad 0.5 \\ \underline{l} x_i & \text{with probability} \quad 0.5 \end{cases} \tag{4}$$

where

$$\underline{l} < p < \bar{l} < q_G < \gamma q_G \tag{5}$$

Thus, when the firm chooses the Exploit strategy, liquidating the firm is better than continuing when $\widetilde{L} = \bar{l}x_1$ while continuing the firm is better than liquidating when $\widetilde{L} = \underline{l}x_1$. In contrast, when the firm implements the Explore strategy, continuing after a good signal is superior to liquidating irrespective of the liquidation value being low or high.

3.4 Bankruptcy Code and Control Rights

The investment strategy of the firm is financed with debt of face value F maturing at date 1 (and the investment need minus the market value of debt is funded through equity). All payments to creditors are made from the firm's cash-flows. If $x_i \geq F$ on date 1, then debt is paid off and the firm becomes an all equity firm. The remaining cash flow $(x_i - F)$, net of taxes (see below), goes to equityholders. For $x_i < F$, the firm cannot meet its contractual payment fully and is in "default." It pays the available amount x_i to creditors and is in arrears for the remaining amount $(F - x_i)$; creditors get the first claim on any future cash flows until they have been fully paid off. Future cash flows depend on whether the firm is continued or liquidated at this point, and on the strategy that is implemented at date 1 if the firm is continued.

The bankruptcy code determines who gets to make these decisions – the decision to liquidate/continue; and contingent on continuation, the decision to implement the strategy (Explore or Exploit). With probability $\pi \in [0, 1]$, the control gets transferred to creditors while with probability $(1 - \pi)$, control remains with equityholders. The parameter π is exogenous and parametrizes the relative creditor-friendliness of the bankruptcy code. A higher π indicates that the bankruptcy code favors creditors. For example, $\pi = 1$ corresponds to creditors having control with perfect certainty in financial distress.

Finally, we denote by τ the tax rate applicable to the firm. Taxes are paid on gross cash flows, but debt provides a tax shield to the firm. For simplicity of exposition, we assume that the tax shields on debt equal τF. While this assumption does not affect our results, it simplifies notation and makes the presentation cleaner.

The nonlinear payoffs of the claimholders generate deviations from the first-best decision to liquidate or to continue and also contingent on continuation, the decision about which strategy to implement at date 1.[8]

4 Analysis

4.1 First Best

The first best corresponds to a world wherein the assumptions underlying the Modigliani and Miller (1958) theorem hold and the investment decision is independent of the financing strategy. In this world, let us first examine in which states the firm would be liquidated and when would it be continued.

[8] Note that renegotiation between claimholders in bankruptcy may be able to eliminate some of these inefficiencies. We follow Acharya, Sundaram and John (2004) in not modeling the renegotiation between the claimholders. However, our results remain valid as long as there are frictions or costs that result in some remaining inefficiency. Dewatripont and Tirole (1994) provide a theoretical model of such frictions; see also Gertner and Scharfstein (1991) wherein coordination problems among public creditors result in inefficiencies in the workout process. The existence of some ex post inefficiencies in financial distress is also consistent with the empirical findings in Andrade and Kaplan (1998).

4.1.1 Exploit

When the Exploit strategy is implemented at date 0, it is optimal to continue when $\widetilde{L} = \underline{l}x_1$ since the expected payoff from continuation px_1 is greater than that from liquidation. In contrast, it is optimal to liquidate when $\widetilde{L} = \bar{l}x_1$ since the expected payoff from continuation px_1 is lower than that from liquidation.

4.1.2 Explore

When the Explore strategy is implemented at date 0, and the signal is 'success', then it is always optimal to continue since the expected payoff from continuation is $q_G\gamma x_2$ is greater than the maximum payoff from liquidation which is $\bar{l}x_2$. In contrast, when the signal is 'failure' after the Explore strategy is implemented, switching to the Exploit strategy is better than continuing with the Explore strategy since $p > q_B\gamma$. Combining this with the optimal decision under Exploit strategy discussed above, we can infer that it is optimal to switch to the Exploit strategy when $\widetilde{L} = \underline{l}x_2$ while it is optimal to liquidate when $\widetilde{L} = \bar{l}x_2$.

4.1.3 Un-levered Firm Values

We denote the values of an all-equity firm following the Exploit strategy and the Explore strategies as $\overline{V_T}$ and $\overline{V_R}$, respectively. The value of the all-equity (or un-levered) firm is the expected value of its cash flows. When an all-equity firm follows the Exploit strategy, its value is given by

$$\begin{aligned} \overline{V_T} &= E\left[\widetilde{x}_1\right] + 0.5E\left[\bar{l}\cdot\widetilde{x}_1\right] + 0.5E\left[p\cdot\widetilde{x}_1\right] \\ &= \left(1 + 0.5\bar{l} + 0.5p\right)(\alpha + 0.5)\ . \end{aligned} \tag{6}$$

The first term in the above expression is the expected value of the first-period cash flow, the second term captures the expected value from liquidating the firm, while the third term is the expected value of the date-2 cash flow, which is the value of the firm at date 1 when it is continued. Note that we argued above that the firm is liquidated with probability $\frac{1}{2}$ when the liquidation value is $\bar{l}x_1$ and firm is continued with probability $\frac{1}{2}$ when the liquidation value is $\underline{l}x_1$.

When an all-equity firm follows the Explore strategy, its value is given by

$$\begin{aligned} \overline{V_R} &= E\left[\widetilde{x}_2\right] + 0.5E\left[q_G\cdot\gamma\widetilde{x}_2\right] + 0.5\left(0.5E\left[\bar{l}\cdot\widetilde{x}_2\right] + 0.5E\left[p\cdot\widetilde{x}_2\right]\right) \\ &= \left(1 + 0.5\gamma q_G + 0.25\bar{l} + 0.25p\right)0.5\ . \end{aligned} \tag{7}$$

The first term in the above expression is the expected value of the first-period cash flow, the second term captures the expected value of the date-2 cash flow when the signal about the Explore strategy is good (i.e. $x_2 \geq 0.5$). The third term captures the value from liquidating the firm which is optimal in the first-best world when the signal about the Explore strategy is bad and when the liquidation value is $\bar{l}x_2$. The fourth term is the expected value of the date 2 cash flow when the firm is continued and it reverts back to the Exploit strategy since the expected payoff from either liquidation ($\underline{l}x_2$) or continuing with the Explore strategy ($\gamma q_B x_2$) is lower than the payoff from continuing with the Exploit strategy (px_2).

Thus, the difference in un-levered firm values is given by

$$\overline{V_R} - \overline{V_T} = 0.25\gamma q_G - \alpha - 0.5\left(\bar{l} + p\right)(\alpha + 0.25) \ . \tag{8}$$

Throughout, we assume that ex ante (at date 0), the Explore strategy provides a higher payoff than the Exploit strategy.

$$\overline{V_R} > \overline{V_T} \tag{9}$$

which requires a mild parametric restriction (see Assumption A1 in Appendix 1).

4.2 Second Best

We deviate from the first best world of Modigliani and Miller (1958) by relaxing two of their assumptions. First, firms pay taxes on their incomes. Second, firms incur deadweight costs when they go bankrupt. We derive these bankruptcy costs as a function of (a) the firm's leverage, (b) the investment strategy that it chooses at date 0, Explore or Exploit, and (c) the bankruptcy code.

The analysis of the Second Best proceeds as follows. We first identify equityholders' and creditors' decisions at date 1 to (a) liquidate, (b) continue by implementing the Exploit strategy, or (c) continue by implementing the Explore strategy. Having identified the decision policy of equityholders and creditors, we calculate the deadweight costs of bankruptcy for the Explore and Exploit strategies under equityholders' control and creditors' control respectively. Having measured these deadweight costs, we derive the expressions for the levered firm values under the two strategies as a function of leverage and the bankruptcy code that the firm faces. Then, we derive the optimal leverage that the firm would chose under the two strategies and the equilibrium levered firm values given this optimal leverage. We finally compare these equilibrium levered firm values to determine the optimal investment strategy for the firm as a function of the bankruptcy code.

Cash flow is enough to pay creditors when $x_i > F$ while the firm would default when $x_i < F$. When the firm defaults, $(F - x_i)$ is owed to the creditors. So in the following, we consider cases where $x_i < F$.

4.2.1 Outcomes for Exploit Strategy in First Period

When the Exploit strategy is chosen at date 0, the cash flow at date 1 does not provide any signal about the efficacy of the Explore strategy in continuation. Therefore, implementing the Explore strategy at date 1 is an inferior strategy for both the equityholders and the creditors. Therefore, the decision to be made at date 1 is whether to liquidate the firm or to continue with the Exploit strategy.

Since the date-1 cash flow is x_1, $(F - x_1)$ is owed to the creditors. Therefore, their payoff when the firm is liquidated equals $\min\left(\widetilde{L}, F - x_1\right)$. If the firm is continued and the Exploit strategy is implemented, then the date-2 cash flow is x_1 with probability p and 0 with probability $(1-p)$. Therefore, the creditors' payoff from continuation is $p \cdot \min(x_1, F - x_1)$.

Since equityholders get the residual payoff after the creditors are paid $(F - x_1)$, the equityholders' payoff from liquidation is $\max\left(\widetilde{L} - F + x_1, 0\right)$ while their payoff from continuation is $p \cdot \max(x_1 - F + x_1, 0)$.

Lemma 1 in Appendix 1 characterizes the liquidation versus continuation decision if creditors take control in bankruptcy. In particular, creditors liquidate efficiently when the liquidation value is high. In this case, creditors' remaining claims are sufficiently large that all future cash flows will accumulate to them. Thus, it is as if they own the firm, and in turn they liquidate efficiently. In contrast, when the liquidation value is low, creditors liquidate inefficiently when the first-period cash flow is relatively high. In this case, the concavity of creditors' claims kicks in, and they liquidate excessively (compared to the first best).

Lemma 2 in Appendix 1 describes formally the decision when equityholders take control in bankruptcy. Equityholders continue efficiently when the liquidation value is low. In contrast, when the liquidation value is high, equityholders continue excessively over a range of date-1 cash flows where the convexity of their claims drives them to continue inefficiently.

4.2.2 Outcomes for Explore Strategy in First Period

When the Explore strategy is chosen at date 0, the cash flow at date 1 provides a signal about the efficacy of the Explore strategy in continuation. Conditional on this signal, there are three possible outcomes for the firm at date 1: (a) liquidate, (b) continue with the strategy, or (c) continue but switch to the Exploit strategy.

Creditors' payoff from continuation using the Exploit strategy is $p \min(x_2, F - x_2)$. Similarly, their payoff from continuation using the Explore strategy is $q_j \min(x_2, F - x_2)$ where $j = G$ if the signal from the date 1 cash flow is good while $j = B$ if the signal from the date 1 cash flow is bad.

Since equityholders get the residual payoff after the creditors are paid $F - x_2$, the equityholders' payoff from liquidation is $\max\left(\widetilde{L} - F + x_2, 0\right)$ while their payoff from continuation using the Exploit strategy is $p \max(x_2 - F + x_2, 0)$. Their payoff from continuation using the Explore strategy is $q_j \max(\gamma x_2 - F + x_2, 0)$, where $j = G$ if the signal from the date 1 cash flow is good while $j = B$ if the signal from the date 1 cash flow is bad.

Lemma 3 of Appendix 1 characterizes the outcome when creditors hold control rights in bankruptcy. Intuitively, when the signal about the Explore strategy is good, the outcomes are similar to that in Lemma 1. Creditors liquidate inefficiently when the date-1 cash flow is relatively high. They make the efficient decision to continue with the Explore strategy when the cash flow is relatively low. Note that when the signal is good, the first best action is to continue irrespective of the liquidation value. When the signal is bad, creditors always liquidate when the liquidation value is high. This is efficient because conditional on the signal being bad, continuing with the Explore strategy is dominated by continuing with the Exploit strategy, which is in turn dominated by the decision to liquidate when the liquidation value is high (again, as in Lemma 1). However, when liquidation value is low, creditors liquidate inefficiently for relatively high values of the date 1 cash flow and continue efficiently with the Exploit strategy for relatively low values of the date 1 cash flow. The intuition for this result is analogous to that in Lemma 1.

Lemma 4 provides the case when equityholders take control in bankruptcy. In this case, when the signal is good, equityholders always continue with the Explore strategy. This decision is efficient ex post. In contrast, when the signal is bad, equityholders continue with the Explore strategy for a certain range of date-1 cash flows. This is inefficient since in a first best world, continuing with the Explore strategy is strictly inferior to either liquidating or continuing with the Exploit strategy. However, given the convexity of the equityholders' claims, the small likelihood of a high cash flow gives them asset-substitution motive. Similarly, for a certain range of date-1 cash flows, equityholders continue inefficiently with the Exploit strategy. Importantly, this range of cash flows is higher than the range over which equityholders continue inefficiently with the Explore strategy. This is expected given the convexity of the equityholders' claim and the induced preference for the greater risk in cash flows from the Explore strategy when the signal is bad.

These characterizations of the continuation outcomes under different decision-makers and under different strategy choices at date 0 lead to the following important result comparing the attendant inefficiencies.

4.2.3 Deadweight Costs of Bankruptcy

When the firm chooses the Exploit strategy, the deadweight costs from bankruptcy, denoted by DW_T, can be expressed in the following simple form when creditors and equityholders are in control in bankruptcy, respectively:

$$\begin{aligned} DW_T\,(\pi = 1) &= a_T F^2 \ , \\ DW_T\,(\pi = 0) &= b_T F^2 \ . \end{aligned} \tag{10}$$

Similarly, when the firm follows the Explore strategy, the deadweight costs from bankruptcy, DW_R, take the form:

$$\begin{aligned} DW_R\,(\pi = 1) &= a_R F^2 \ , \\ DW_R\,(\pi = 0) &= b_R F^2 \ . \end{aligned} \tag{11}$$

While the exact expressions for a_T, a_R, b_T, and b_R are provided in Appendix 1, the key result is the following:

Proposition 1: Under creditor-friendly bankruptcy system ($\pi = 1$), the deadweight costs of bankruptcy are higher for firms following the Explore strategy compared to those for firms following the Exploit strategy. In contrast, under debtor-friendly code, the deadweight costs of bankruptcy are lower for firms following the Explore strategy compared to those firms following the Exploit strategy. Formally, under Assumption A2,

$$(a)\ a_R > a_T \ , \text{ and} \tag{12}$$

$$(b)\ b_R < b_T \ . \tag{13}$$

This result arises due to the fact that equityholders continue the firm too often while creditors liquidate the firm too often. Since the Explore strategy is less likely to succeed initially, the net effect is that deadweight costs are lower for firms following the Explore strategy than for firms following the Exploit strategy under debtor-friendly code, and the converse holds under the creditor-friendly code.

4.2.4 Levered Firm Values

We now consider the more general bankruptcy code where control rights are transferred to creditors with probability π and to equityholders otherwise. Note that the levered firm value is equal to the value of the all-equity firm plus the tax shields from debt minus the deadweight costs of bankruptcy. The value of the tax shields is calculated as the difference in the taxes paid by the levered firm, when it is solvent, and its all-equity counterpart. Therefore, the levered firm values under the Exploit and Explore strategies, as a function of face value of debt F and bankruptcy code π, are as follows:

$$V_T(F,\pi) = (1-\tau)\overline{V_T} + \int_0^{1+\alpha} \tau x_1 dx_1 - \int_F^{1+\alpha} \tau (x_1 - F) dx_1 - \left[\pi a_T F^2 + (1-\pi) b_T F^2\right] \text{ , and} \quad (14)$$

$$V_R(F,\pi) = (1-\tau)\overline{V_R} + \int_0^{1} \tau x_2 dx_2 - \int_F^{1} \tau (x_2 - F) dx_2 - \left[\pi a_R F^2 + (1-\pi) b_R F^2\right] \text{ .} \quad (15)$$

4.2.5 Optimal Leverage and Equilibrium Levered Firm Values

We first examine the optimal leverage for a given investment strategy, compute the equilibrium firm value under this optimal leverage for that strategy, and then compare firm values across strategy to determine the equilibrium investment strategy.

The firm chooses F at date 0 to maximize its value given the investment strategy. Let the optimal leverage under the Explore and Exploit strategies be F_R^* and F_T^*, respectively, and the corresponding equilibrium firm values be V_R^* and V_T^*. Then, we obtain that

PROPOSITION 2: As the bankruptcy code becomes more creditor friendly (π increases), the difference in the optimal leverage between firms following the Exploit strategy and the Explore strategy increases. Formally, under Assumption A2,

$$\frac{d\left(F_R^* - F_T^*\right)}{d\pi} < 0 \text{ .} \quad (16)$$

As the bankruptcy regime becomes more creditor-friendly, firms that follow the Explore strategy reduce their leverage since the deadweight costs for such firms are comparatively higher under creditor control than under equityholder control. In contrast, firms that follow the Exploit strategy increase their leverage since the deadweight costs for such firms are comparatively lower under creditor control than under equityholder control.

Given this, we obtain our main theoretical result:

PROPOSITION 3: As the bankruptcy code becomes more creditor friendly, the firm value from following the Explore strategy decreases while the firm value from following the Exploit strategy increases. Formally, under Assumption A2,

$$\frac{d\left(V_R^* - V_T^*\right)}{d\pi} < 0 \text{ .} \quad (17)$$

In other words, as the bankruptcy regime becomes more creditor friendly, firms find it more valuable at the margin to follow the Exploit strategy than to follow the Explore strategy. From Proposition 1, we know that firms that follow the Explore strategy face greater bankruptcy costs under creditor control than under equityholder control. Therefore, when the bankruptcy code becomes more creditor friendly, these firms respond to this change by lowering their leverage. This reduces the tax shields from debt and thus reduces the value of such firms. In contrast, firms that follow the Exploit strategy face lower bankruptcy costs under creditor control than under equityholder control. Therefore, when the bankruptcy code becomes more creditor friendly, these firms respond to this change by increasing their leverage. This increases the tax shields from debt and thus enhances the value of such firms. Therefore, when the bankruptcy code becomes more creditor friendly, the value of the firms following the Explore strategy decreases while the value of firms following the Exploit strategy increases.

We also find, given some restrictions on our parameters, that the firm value under the Exploit strategy is higher than the firm value under the Explore strategy in countries with stronger creditor rights ($\pi \geq \overline{\pi}$) while the value under the Explore strategy is higher in countries with weaker creditor rights ($\pi < \overline{\pi}$). Therefore, firms in all industries would pursue more innovation in countries with weaker creditor rights. This is because in countries with stronger creditor rights, firms in all industries find it ex ante beneficial to switch to the Explore strategy to avoid the ex post higher likelihood of the creditor liquidating their investments.

5 Empirical Evidence

We test the prediction in Proposition 3 that the difference in the value from following the Explore strategy and the Exploit strategy decreases as the bankruptcy code becomes more creditor friendly. The test can be described best using the following example. Consider two industries: Biotechnology and Apparel & Textile. Clearly, firms in the Biotechnology sector have a greater propensity to innovate when compared to firms in the Apparel industry. Given this variation in the propensity to innovate between Biotechnology and Apparel, Proposition 3 states that the difference in innovation between Biotechnology and Apparel would be greater in the United States than in Germany because the rights provided to creditors in bankruptcy are weaker in the United States than in Germany. We implement the econometric variant of this different-in-difference test by comparing inter-industry differences in innovation across various bankruptcy regimes: first, in the cross-section of countries, and second, in the time-series that exploits changes in creditor rights.

We first describe our data, next the test design, and, finally, the results and robustness checks.

5.1 Data

We use patents from the NBER Patents File (Hall, Jaffe and Trajtenberg, 2001) to measure innovation and to classify classes of firms based on their propensity to pursue innovation. Our data on the country-level index of creditor rights comes from Djankov, McLiesh and Shleifer (2005). Although the patent data is available from 1963 onwards, the information on the country-level index of creditor rights provided by Djankov et al. (2005) starts only in 1978. Therefore, the time period of our sample is 1978-2002. Since the creditor rights data are now standard, we focus below on describing the patents data, our measures of innovation, and ranking of industries based on technological innovation intensity.

Patents have long been used as an indicator of innovative activity and technological change in both the micro- and macro-economic studies (Griliches, 1990). Although patents provide an imperfect measure of innovation, there is no other widely accepted method which can be applied to capture technological advances.[9] Nevertheless, we are aware that using patents has its drawbacks. Not all firms patent their innovations, because some inventions do not meet the patentability criteria and because the inventor might rely on secrecy or other means to protect its innovation. In addition, patents measure only successful innovations. To that extent, our results are subject to the same criticisms as previous studies that use patents to measure innovation (e.g., Griliches, 1990; Cockburn and Henderson, 1998; Kortum and Lerner, 1999).

The NBER patent dataset provides among other items, annual information on patent assignee names, on the number of patents, on the number of citations received by each patent, on the technology class of the patent (described below in detail) and on the year that the patent application is filed. The dataset covers all patents filed with the US Patents Office (USPTO) by firms from around 70 countries. We exploit the technological dimension of the data generated by patent classes and sub-classes. During the patent examination process, patents are assigned to detailed technologies as defined by the "patent class" and "sub-class." The USPTO performs these assignments with care to facilitate future searches of the prior art in a specific area of technology (Kortum and Lerner, 1999). Since the year of application captures the relevant date of the innovation for which a patent is filed, we date our patents according to the year in which they were applied for. This also avoids anomalies that may be created due to lag between the date of application and the date of granting of the patent (Griliches, Pakes, and Hall, 1987). Note that although we use the application year as the relevant year for our analysis, the patents appear in the database only after they are granted. Hence, we use the patents actually granted (rather than the patent applications) for our analysis.[10,11]

[9] An an alternative to patents as proxies of innovation, R&D spending across different industries could be a potential proxy for innovation intensity. However, in a cross-country setting, this presents several challenges. First, accounting norms, particularly whether R&D is capitalized or is expensed, would have a mechanican effect on R&D spending. Second, differences in the level of protection provided to Intellectual property would account for differences in investment in R&D in different countries. Using US patents as a proxy of innovation avoids these pitfalls.

Furthermore, Pakes and Griliches (1984) emphasized that there is a strong relationship between R&D and the number of patents received at the cross-sectional level, across firms and industries. The median R-squared is on the order of 0.9. This indicates that patents may indeed be a good indicator of unobserved inventive output.

[10] A caveat about potential biases created by the use of application year, particularly in the case of foreign patents, is in order. Since foreign firms usually file patents with the domestic patent office and then with the USPTO, readers may believe that the application year recorded with the USPTO does not capture the exact timing of the innovation. However, the Paris Convention which governs such firms filing both in the domestic and foreign country, mandates that if the inventor files a foreign patent application in any other Paris Convention signatory state within 12 months of the domestic filing, overseas patent-granting authorities will treat the application as if it were filed on the first filing date. Therefore, the application year recorded with the USPTO would coincide with the application year for the domestic patent of the foreign firm.

[11] Readers may query how do we treat the patents that are filed by US subsidiaries of foreign firms and does the inclusion/ exclusion of such patents affect our results. We identify such patents as those where the country of the "assignee" is non-US but the country of the "inventor" is recorded as US. Of the 3,333,701 patents in our sample, we identify 21489 patents (0.6%) issued to US subsidiaries of foreign companies. Not surprisingly, excluding these patents does not change our results.

5.1.1 Why use USPTO Patents to Proxy Innovation?

Employing patents filed with the USPTO alleviates concerns that may arise when using patents filed in different countries due to differences in protection provided to patents as also the heterogeneity in the patent systems. Kortun and Lerner (1999) cite Wegner (1993) to state that "there are really but two different systems among the major patent systems of the world, an 'international' system that is found in Europe and Japan, and an 'American' system." According to Kortum and Lerner (1999), the key features of the American system include: (i) the awarding of the patent to the first to discover an innovation, rather than the first to file for an invention; (ii) the principle that patent applications would not be published until they were awarded; and (iii) the broad interpretation of patent scope through the doctrine of equivalents.

However, using patents filed with the USPTO introduces potential biases since it is likely that foreign firms file patents with the USPTO because they need to sell their products in the US. In this case, it is likely that foreign firms in an innovation intensive industry such as Biotechnology would file more patents with the USPTO than their counterparts in industries such as Textiles and Apparel. However, since the US had the weakest creditor rights among all countries during our sample period, this bias works against us finding that the difference in patents between Biotechnology and Apparel decreases as creditor rights become stronger.

5.1.2 Proxies for Innovation

We use two broad metrics to measure innovation. The first is a simple patent count of the number of patents that were filed in a particular year in a specific patent class and sub-class. The second metric of innovative activity that is used in most of the analysis measures the importance and drastic nature of innovation by examining the citations that are made to patents. This measure is motivated by the recognition that the simple count of patents has its limitations. One of the biggest problems is that it does not distinguish breakthrough innovations from less significant or incremental technological discoveries. Pakes and Shankerman (1984) and Griliches, Pakes, and Hall (1987) show that the distribution of the importance of patents is extremely skewed, i.e., most of the value is concentrated in a small number of patents. Trajtenberg (1990), Albert et al. (1991), and Hall et al. (2005) among others demonstrate that patent citations are a good measure of the value of innovations. Intuitively, the rationale behind using patent citations to identify important innovations is that if firms are willing to further invest in a project that is building upon a previous patent, it implies that the cited patent is influential and economically significant. In addition, patent citations tend to arrive over time, suggesting that the importance of a patent may be revealed over a period of time and may be difficult to evaluate at the time the innovation occurred. And, finally, citations also help control for country-level differences arising in the number of patents due to differences in the number and size of firms, and, in turn, of innovations.

5.1.3 Summary Statistics

Panel A of Table 1 shows the summary statistics for the number of patents filed per year over the sample period 1978-2002 while Panel B shows the number of citations per year to these patents across different industry categories. The number of patents filed per year and the number of citations per year to these patents vary with the industry category, with Computers and Communications having the highest number of patents filed per year and the highest number of citations to these patents per year, and the more mature Mechanical industry exhibiting the lowest values on both counts. The reasons for these differences are primarily technological. Cohen et al. (1996) contrast between discrete and complex technologies and argue that firms file more patents and cite each other's patent more when the technology is "complex".

Note also, however, that the minimum number of patents in a year is smaller for Computers and Communications relative to Mechanical. This is an important observation suggesting that the technological innovation intensity of industries has changed in a relative fashion over time, a point that has also been stressed by Hall, Jaffe and Trajtenberg (2001) in their Figure 5 which shows that there have been changes in the share of patents occupied by the different industry categories over the period 1978-2002. The principal reason is the inter-temporal variation in the level of innovation across different industries, particularly due to the arrival of technological shocks. Kortum and Lerner (1999) find for example that the number of patents filed in Biotechnology and Software industries has risen considerably since the late 1970s, both absolutely and as a share of total patenting in the United States.

Finally, Table 2 provides these summary statistics for the US and Germany, which have creditor rights index of one and three, respectively, over our sample period. We discuss these numbers at a later stage in the context of our cross-sectional tests.

5.2 Overall Test Design

We follow Rajan and Zingales (1998) in implementing our difference-in-difference tests: Do countries with weaker creditor rights exhibit greater relative innovation in industries that are technologically more innovative compared to less innovative industries? The "industry" level classification we employ pertains to the patent sub-classes in the data. We identify an industry's (patent sub-class') propensity to innovate by using the data on patents filed by US firms in that industry with the US Patents Office. We then make the assumption that the propensity to innovate is driven primarily by the technological characteristics of firms in that industry. Cohen, Nelson and Walsh (1996) find in their survey of patenting across various US industries that the propensity to patent is largely driven by technological characteristics of an industry. Hence, we reason that these technological characteristics carry over to other countries. For example, the correlation in industry ranking between the US and Germany is 0.765 on average in the time-series, its value ranging from a minimum of 0.69 to a maximum of 0.86.

The choice of the US for the ranking of industries is also natural for several other reasons: the US has the most populated data across various patent sub-classes and over time; the US has had the weakest creditor rights or the most debtor-friendly bankruptcy code over our sample period; the US had the most well-developed financial markets over our sample period and these have been shown to be necessary for funding of constrained but high-growth sectors (Rajan and Zingales, 1998); and, last but not the least, the US has had the most vibrant research environment in universities and the most open immigration policy for enrolling scholars in these universities.

Next, we describe our cross-sectional test and then the time-series one.

5.3 Cross-sectional Test

We perform the cross-sectional difference-in-difference tests using the model described below:

$$\begin{aligned} y_{ict} &= \beta_0 + \boldsymbol{\beta}_1 \cdot (CreditorRights_{ct} * PatentIntensity_{it}) \\ &\quad + \beta_2 \cdot CreditorRights_{ct} + \beta_3 PatentIntensity_{it} + \beta X + \varepsilon_{ict} \ , \end{aligned} \tag{18}$$

where y is the natural logarithm of a measure of innovation for the USPTO patent sub-class (i), country (c) and the year when the patent was applied for (t). The principal coefficient of interest is β_1 since this captures the difference-in-difference that we are trying to measure, the hypothesis based on Proposition 3 being that $\beta_1 < 0$. The control variables include indicator variables for each country, for each of the thirty-six industry categories as aggregated from sub-classes in Hall, Jaffe and Trajtenberg (2001),[12] and for each application year in our sample. We also include indicator variables for the legal origin of the country[13], and the number of firms in the industry sub-class.

We compute $PatentIntensity_{it}$ for patent sub-class i in year t as the median number of patents applied by US firms in year $(t-1)$. As justified before, instead of using a fixed time window to classify industries based on their propensity to patent, we use this moving window to measure the Patent Intensity so as to capture the inter-temporal changes in the propensity to patent caused by technological shocks.

5.4 Time-series Test using *Changes* in Creditor Rights

We use the changes in creditor rights in various countries to perform a third-difference test. The model we test is described below:

$$\begin{aligned} y_{ict} &= \beta_0 + [\beta_1 + \boldsymbol{\beta}_2 \delta_{ct} + \beta_3 \delta_c + \beta_4 \delta_t] * PatentIntensity_{it} + \\ &\quad + \beta_5 \cdot \delta_{ct} + \beta X + \varepsilon_{ict} \ , \end{aligned} \tag{19}$$

where as in the cross-sectional test y is the natural logarithm of a measure of innovation for the USPTO patent sub-class (i), country (c) and the year when the patent was applied for (t). δ_{ct} is an indicator variable which equals one for country c and years $t \geq m+1$ if a creditor rights reform initiated in year m increased the rights provided to creditors. The dummy equals 1 for country c and years $t < m+1$ if a creditor rights reform initiated in year m decreased the rights provided to creditors.

This model is equivalent to

$$\frac{\partial y_{ict}}{\partial PatentIntensity_{it}} = \beta_1 + \boldsymbol{\beta}_2 \delta_{ct} + \beta_3 \delta_c + \beta_4 \delta_t \tag{20}$$

[12] Since the number of patent sub-classes is very large (about 130,000 in all), we cannot include so many industry fixed effects in our tests. Hence, we consider aggregated level of 36 industry categories, specified by Hall, Jaffe and Trajtenberg (2001), which correspond roughly (even if imperfectly and somewhat coarsely) to the 2-digit SIC level industries. Summary statistics for these 36 industry categories, along the lines of Table 1, are contained in Appendix 2 for two sample countries (US and Germany).

[13] This enables us to exploit the "within" legal origin variation in creditor rights. Djankov et al. (2005) have shown in their study of 129 countries that legal origin is an important cross-sectional determinant of creditor rights in a country by.

$$\iff \quad \boldsymbol{\beta}_2 = \left[\left.\frac{\partial y_{ict}}{\partial PatentIntensity_{it}}\right|_{after} - \left.\frac{\partial y_{ict}}{\partial PatentIntensity_{it}}\right|_{before} \right]_{treated} - \left[\left.\frac{\partial y_{ict}}{\partial PatentIntensity_{it}}\right|_{after} - \left.\frac{\partial y_{ict}}{\partial PatentIntensity_{it}}\right|_{before} \right]_{control} \tag{21}$$

Therefore, the coefficient β_2 captures the triple difference that we are looking to measure, the hypothesis based on Proposition 3 being that $\beta_2 < 0$. The set of control variables include indicator variables for each country, for each of the thirty-six industry categories, and for each application year in our sample. We also include indicator variables for the legal origin of the country, and the number of firms in the industry sub-class.

5.5 Empirical Results

5.5.1 Evidence from Cross-sectional Tests

Tables 3-6 display the results of the cross-sectional tests described in Section 5.3. Table 3 shows the results using logarithm of the number of patents while Table 4 shows the same using the logarithm of the number of citations as the proxy for innovation. We employ several specifications. Column 1 tests the basic specification which contains only the explanatory variables of interest measured using the median number of patents for firms in the US. In columns 2 and 3 we examine the robustness of this result for the time periods 1978-1990 and 1991-2002. In column 4, we proxy patenting intensity using the average number of patents measured for firms in the US. Across each of these specifications, the coefficient of the interaction term is quite statistically significant. In column 5, we add the number of firms in each patent sub-class in a country in a specific year and find that the coefficient of the interaction term stays negative. However, we find that the R-squared for the regression increases significantly indicating that the results on the aggregate innovation may be driven by the number of the firms. This motivates us to examine the results on the innovation done by the median firm in our sample (see below in Table 5). In column 6, we add indicator variables for the legal origin of the country while we add industry, country and application year fixed effects respectively in columns 7 to 9. Apart from all the country variables, in column 10, we include the entire set of fixed effects while in column 11, we add fixed effects at the level of each industry for each country. We find that across all our specifications, the coefficient of the interaction term stays uniformly and strongly negative (except for Column 3 of Table 4 which corresponds to the sub-period 1991 to 2002 for number of citations to patents as the measure of innovation intensity).

The economic magnitude of the effect of the interaction term is significant too. For example, using the specification in Table 3, Column 6 (which seems to be the most parsimonious, yet one with a relatively good fit), we find that $ln(y) = 0.135 *$ Median Patents in Subclass $- 0.026 *$ Creditor Rights * Median Patents in Subclass. Consider two patent sub-classes which differ by 1 patent per year in the number of patents that the median firm receives. Let the number of patents in these sub-classes be y_2 and y_1, respectively, where y_2 is the more innovative sub-class. If Creditor Rights index takes the value of one, then $ln(y) = 0.109 *$ Median Patents in Subclass. Therefore, $ln(y_2/y_1) = 0.109$, or in other words $y_2/y_1 = 1.115$. That is, the more innovative patent class (corresponding to y_2) would generate 11.5% more patents in a year than the less innovative one. If instead the Creditor Rights index was four (the maximum possible value), then we obtain that $ln(y) = 0.031 *$ Median Patents in Subclass. Therefore, $ln(y_2/y_1) = 0.031$ which implies that $y_2/y_1 = 1.031$. Thus, more innovative patent class would generate 3.1% more patents in a year than the less innovative one. So, when we go from a country with Creditor Rights index of 1 to 4, the difference in innovation between two adjacent patent classes magnifies close to four times.

The strength of this effect is illustrated in Figures 2A through 2D which plot the time-series of ratio of number of patents of an innovative industry relative to a benchmark less innovative industry (Apparel & Textile) for the US and for Germany (creditor rights index of 3 during our sample period). The innovative industry is taken to be Computer Peripherals in 2A, Information Storage in 2B, Surgery and Medical Instruments in 2C, and Biotechnology in 2D. Summary statistics for innovation intensity in the US and Germany in these (and other) sub-classes can be found in Appendix 2. In each case, the ratio for the US is substantially higher than that for Germany. In 1998, the factor for the US is about seven times as high as that for Germany in case of Computer Peripherals, and even higher in case of Information Storage and Surgery and Medical Instruments.

Furthermore, this factor is increasing in most cases over time right from 1978 (the beginning of our data and in fact the year the US passed the Bankruptcy Reform Act making its code even more debtor-friendly). Similar results are obtained if alternative benchmarks are employed for the less innovative industry and alternative countries with strong creditor rights are picked (e.g., in Figure 4 in Appendix employing Japan, which like Germany, also had a creditor rights index of 3 over our sample period).

Next, in Table 5, we display the results of the cross-sectional tests for the innovation done by the typical firm in our sample. First, we employ the median number of patents held by a firm in the (country, sub-class, year) sample (Columns 1–3) and its mean counterpart (Columns 4–6). Then, we also employ the median number of firm-level citations (Columns 7–9) and its mean counterpart (Columns 10–12). We include dummies for the legal origin, the number of firms, and the battery of fixed effects described earlier as our control variables. Across all our specifications, the coefficient of the interaction term stays strongly negative and statistically significant.

In Table 6, we examine how the different components of creditor rights in a country affect the difference in innovation across the different industries. We find the interaction terms corresponding to no automatic stay on secured creditor claims, and the incumbent management not managing the firm during its reorganization are the ones that emerge strongly negative and overall robust. No automatic stay on secured creditor claims implies a greater likelihood of inefficient liquidations while the incumbent management not managing in reorganization implies a greater disincentive to undertake risk ex ante. Therefore, consistent with the trade-offs highlighted by our theory, the likelihood of inefficient liquidation and the resultant lack of incentive to undertake risk ex ante significantly impact the difference in innovation between different industries in a country. The interaction of creditor rights with the difficulty of reorganization measured by the requirement of creditor consent is generally negative but insignificant in Columns 5 and 7, whereas the interaction with whether secured creditors get paid first is (somewhat surprisingly) positive in all specifications.[14]

[14] One possible interpretation for this latter result could be that secured creditors getting paid first leads to greater presence of bank debt in firm's capital structure, making reorganization easier relative to public or arm's length debt.

5.5.2 Evidence from Time-series *Changes* in Creditor Rights

In the strongest piece of evidence supporting our theory, we consider the above interaction effect for the "treatment" sample of countries where creditor rights underwent a change during our sample period, and the "control" sample of other countries. This time-series test has a number of attractive features: First, it is not subject to the omitted-variables bias often raised as an objection to cross-country regression results (our difference-in-difference approach notwithstanding); second, it removes the onus on the empiricist in terms of having a benchmark such as the US in cross-country tests (which some might argue has had a rather special twentieth century, and especially the latter part with regard to innovation); and, finally, it provides point estimates on the effect of bankruptcy codes on innovation that are derived from experiments of greatest relevance to policies concerned with promoting innovation.

There are a total of twelve countries which underwent a change in creditor rights index over our sample period. Seven of these (Canada, Finland, Indonesia, Ireland, Israel, India and Sweden) experienced a decrease in creditor rights by one, and five (Denmark, United Kingdom, Lithuania, Romania and Russian Federation) experienced an increase. Table 7 lists these countries and their year of change in creditor rights, and the total number of patents before and after the change.

Table 8 presents the results of the time series test described in Section 5.4. In Panel A, we interact the dummy which captures the treatment effect of a change in creditor rights with industry-level innovation intensity. We adapt Bertrand and Mulainathan (2003) to estimate the difference-in-difference in our interaction variable. We include country and application year dummies, and interact these dummies with innovation intensity. Notice that compared to the usual difference-in-difference specification which contains dummies for treatment groups and treatment periods, including dummies for all the countries and all the years leads to a much stronger test since we are able to control for time-invariant country-specific effects as well as time-varying effects that are common to all countries. In Panel B, we employ a similar specification but proxy innovation intensity through two groups - one with sub-classes where number of patents is higher than median and the other with number of patents below the median.

We find the coefficient of the interaction term in Panel A to be again strongly negative, thus providing the strongest evidence in support of Proposition 3. We also notice that the effect is robust to exclusion of the US from control sample while measuring innovation by the median number of patents at sub-class level. When the dependent variable is the logarithm of citations, the coefficient of the interaction term is statistically significant only at the 10% level. Since citations to patents take time to accumulate and therefore suffer from higher bias due to truncation, we would expect this smaller impact of the creditor rights change on citations.

Furthermore, the effect is economically of a higher magnitude than that obtained in the cross-sectional tests. From Column 1 of Panel B, we find that for the control group of countries with no change in creditor rights, the more innovative industry had 3.5% more patents in a year than the adjacent less innovative one. In contrast, in the treatment group, the countries that had an increase in creditor rights, the difference in innovation between two adjacent industries fell to 1.1%, and in countries where creditor rights decreased, the difference in innovation between two adjacent industries increased to 5.9%. Thus, an increase in creditor rights made the cross-country difference in the intensity of innovation one-third, while a decrease almost doubled this difference.

To summarize, consistent with our cross-country findings, the within-country effect of an increase in creditor rights index is to lower the innovation intensity more for industries that are technologically more likely to innovate. Thus, after controlling for unobserved heterogeneity of various kinds, we find that a decrease in the creditor rights leads firms in innovative industries to innovate even more compared to firms in conservative industries, suggesting a causal effect of bankruptcy codes on innovation in the economy.

It is interesting to dissect as to whether the interaction effect arises purely from a shift in innovation intensities of more innovative industries, or due to a shift in all industries but a greater relative shift for more innovative industries. Panel C answers this question by interacting the treatment dummy for change in creditor rights with a dummy for industries with above median number of patents and below median number of patents. Estimates reveal that both sets of industries experience a decrease in innovation following an increase in creditor rights, however the more innovative set experiences a far greater decrease giving rise to the differential effect estimated in Panel B. This finding suggests that the effect of strong creditor rights in discouraging innovation is pervasive but has a magnitude that is particularly high in technologically innovative industries.

Causal effect of creditor rights changes: It is important to understand what caused the changes in creditor rights. Was it the case that creditor rights changed for reasons other than promoting growth and innovation, so that our evidence above can be interpreted truly as a causal effect of the change on innovation? Or, was it the case that creditor rights changes were part of an overall package to promote growth and innovation, so that the evidence above exhibits some reverse causality? Note that in *either* of these cases, the evidence lends support to our theory that creditor rights can affect the extent of innovative activity.

Nevertheless, we examine reverse causality in Columns (4) and (8) of Table 8 by examining the dynamic effect of these creditor rights changes. If the creditor rights change was effected to promote growth and innovation, we might expect an "effect" of the change even prior to the change itself. To examine this, we follow Bertrand and Mulainathan (2003) in decomposing our Treatment Dummy variable into three separate time periods – Treatment Dummy (-2,-1) captures any effects from two years before to a year before the change in creditor rights, Treatment Dummy (0) captures the effect in the year of the change, and Treatment Dummy ($\geq$1) captures the effect one year and beyond. If the coefficient of the interaction of the dummy variable Treatment Dummy (-2,-1) with patenting intensity is economically and statistically significant, that may be symptomatic of reverse causation. In fact, in column (4) of Table 8, we find that this coefficient is of the opposite sign and is statistically and economically insignificant. Interestingly, we observe that the coefficient of the interaction of patenting intensity with these dummies is positive for Treatment Dummy (-2,-1), becomes negative for Treatment Dummy (0) and becomes an economically and statistically large negative number for Treatment Dummy (≥ 1). This direction in the magnitudes of these three treatment dummies is consistent with a causal effect of creditor rights changes on the difference in innovation across various industries.[15] While the coefficient of Treatment Dummy (≥ 1)'s interaction with patenting intensity is not statistically significant when the dependent variable is the logarithm of citations (see column (8)), the coefficients for the interactions with Treatment Dummy (≥ 1) and Treatment Dummy

[15] The direct effect of the creditor rights change on aggregate innovation, as measured by the coefficients of these dummies, suggests that there may have been an "effect" on aggregate innovation even two years prior to the change. However, our main prediction is about the differential impact of the creditors rights change, which leads us to focus on the coefficients of the interaction variables.

(0) are negative, which is in contrast to the positive coefficient on the interaction with Treatment Dummy (-2,-1). The lack of statistical significance on the interactions with Treatment Dummy (≥ 1) is not surprising since the coefficient of this interaction in column (7) was barely statistically significant in the first place. Therefore, the results in columns (4) and (8) taken together suggest that a decrease (increase) in creditors rights in a country led to more (less) innovation particularly in the innovation intensive industries.

Discussion on the causes of creditor rights changes: We now discuss the reasons behind the changes in the creditor rights in our "treatment" sample of countries.

The weakening of creditor rights in Israel in 1995 was precisely to provide entrepreneurship a boost. It represented a greater "tolerance" towards debt undertaking and the over-extended borrowers who fell into financial trouble. In fact, "the changing orientation of Israel's economy from being socialist-based to more capitalistic can also be linked to the liberalization of the fresh-start policy. As entrepreneurship became a more widely-accepted activity in Israel, society began to acknowledge the incentives a more liberal fresh-start policy could provide to a private market economy" (Efrat, 1999).

Other changes have not necessarily occurred to promote only such fresh starts. Consider, for instance, the decrease in creditor rights in Canada in 1992 and in India in 1993. The primary objective of the change in Canada was to increase the chances of survival of businesses that are experiencing financial difficulties, and, as a consequence, to save jobs (Martel, 1994), an ex-post objective rather than an ex-ante one to promote innovation per se. In case of India, the motivation was to protect the domestic, uncompetitive firms who had been forced into bankruptcy by the deregulation and introduction of foreign competition in 1991 (Kang and Nayar, 2004), a lobbying-based outcome rather than one aimed purely at issues of efficiency.

In contrast, the weakening of creditor rights in Finland in 1993 (by two points) and Indonesia in 1998 were prompted by the severity of ongoing crises. In the case of Finland, the real GDP had dropped by about 14% and unemployment had risen from 3% to nearly 20%. The creditor rights were however part of a larger stimulus package in both countries. In Finland, restrictions on foreign ownership were completely abolished and the accounting legislation was improved. These measures were attributed the acceleration in development of the stock market and the venture capital activity, and the rebounding of employment rates (Hyytinen, Kuosa and Takalo, 2001). In Indonesia, bankruptcy law reforms included secured transactions law reforms and reforms to anticorruption legislations.

Finally, the weakening of creditor rights in the United Kingdom in 1985 was largely to mirror the success of the United States Chapter 11 bankruptcy in providing a formal structure for reorganization of solvent but illiquid institutions (Armour, Cheffins and Skeel, Jr, 2002), whereas their strengthening in Russia in 1994, Lithuania in 1995 and Romania in 1999 were a part of their transition and were viewed as a way to boost lending (Haselmann, Pistor and Vig, 2006) and make more efficient the bankruptcy systems ridden by inexperienced judges.

These examples illustrate the following important points. First, creditor right changes have sometimes been introduced precisely to promote growth and innovation. Second, these changes have often arisen due to lobbying and job-saving objectives, exogenous to the issue of promoting innovation. And, third, these changes have also often been timed to turn around economies that are in crises or at the verge of growth spurts, but importantly, creditor right changes have been an important part of the overall stimulus package. These facts together, along with our empirical tests on reverse causality described earlier, give us confidence that the relationship between creditor right changes and innovation unearthed in our time-series tests is indeed economically meaningful and causal (in one direction or another).

5.5.3 Evidence from Leverage Choice in G-7 Countries

Having confirmed the real implications of our model, we examine next the financial implications. Specifically, we test Proposition 2 that an innovative firm will be financed with relatively less leverage than a conservative firm, when creditor rights become stronger. This difference of difference test is performed along the lines of a specification similar to that in equation (18), with y_{ict} being replaced by leverage for a given firm in country c in year t, and the measure of innovation (patenting intensity) being employed on the right hand side at the level of 2-digit SIC industry of the firm in that country. To be consistent with the existing literature (e.g., Rajan and Zingales, 1995), we include as control variables other firm characteristics (tangible assets measured as property, plant and equipment by assets, profitability measured as EBITDA by assets, log of sales, and market to book ratio) as well as their interactions with country dummies.

Due to limits on data availability, we focus on the G-7 countries using Worldscope database over the period 1990 to 2005. Panel A of Table 9 shows the values of the four components and the aggregate score for creditor rights for these G-7 countries (from LLSV (1998)). During our sample period, France has the lowest score of 0 while UK has the highest score of 4.

Again, we test whether the coefficient β_1 on the interaction between creditor rights and innovation intensity is negative. This is indeed what we find in Panel B of Table 9. In particular, when creditor rights are stronger, innovative industries take on relatively less leverage compared to other industries. This finding stays robust to different measures of leverage (book, market, inclusive of all non-equity liabilities, and net of cash and cash equivalents), though it is statistically insignificant in the case of net market debt as the leverage proxy.

This finding is important for two reasons. First, it shows that the model finds support not only in its main result, which is that weaker creditor rights lead to greater innovation, but also in the specific mechanism at play in the model, which is that leverage is costly as a means of financing for innovative firms when creditor rights are strong. In other words, firms in innovative industries do appear to unwind the effect of stronger creditor rights. They do so by undertaking smaller quantities of debt and keeping more cash reserves in order to pursue more innovative projects. Second, this finding suggests that one ought to be cautious about the approach in law and finance literature which ascribes greater lending being associated with stronger creditor rights (at least implicitly) as an improvement in welfare and efficiency. Our model and results lead one to view such claims with caution as the change in creditor rights may be associated with a change in the underlying real activity, and the reason why stronger creditor rights lead to greater lending is because they discourage innovation in favour of more standard projects that can sustain greater borrowing.

5.5.4 Growth Effects

Following the endogenous growth literature referenced earlier, an important question to ask from the perspective of a social planner is the following: how does the differential impact of creditor rights on different industries, depending upon their innovation intensity, affect the growth rates of these industries? We turn to this question now. We follow Rajan and Zingales (1998) and employ as our dependent variable the growth rate in value added and in real value added over the period 1978-1992 for each ISIC (manufacturing) industry in a country. To account for the effect of external financial dependence and its interaction with various measures of a country's financial development, we add both to our specifications and test whether the coefficient of the interaction between creditor rights and patenting intensity accounts for growth over and above these effects.

We display the results of this test in Table 10. In columns (1) and (2), we include the interaction of creditor rights with patenting intensity and their levels with the country level legal origin variables. The dependent variables in columns (1) and (2) are the continuously compounded growth rates is value added and real value added respectively. In columns (3) and (4), we add the measures of financial development that Rajan and Zingales (1998) use while in columns (5) and (6), we add the financial development measures along with its interaction with an industry's external financial dependence. Across all these specifications, we find that the coefficient of the interaction between creditor rights and patenting intensity is strongly negative.

The economic magnitude of the effect of the interaction term is significant too. For example, using the specification in column (6) of Table 10 (which controls for all the Rajan and Zingales (1998) effects and has the best fit for real value added), we find that $g = 0.051 *$ Median number of Patents in ISIC $- 0.015 *$ Creditor Rights * Median number of Patents in ISIC. Consider two ISIC industries which differ by one patent per year in the number of patents that the median firm receives. Let the growth rates in these industries be g_2 and g_1, respectively, where g_2 corresponds to the more innovative industry. If Creditor Rights index takes the value of one, then $g = 0.036 *$ Median number of Patents in ISIC. Therefore, $g_2 - g_1 = 0.036$. Therefore, over the period 1978-1992, the more innovative industry (corresponding to g_2) had a 3.6% *higher* continuously compounded growth rate than the less innovative industry. Since the average (median) growth rate in real value added across all manufacturing industries is 3.42% (3.14%) while the standard deviation in the growth rates is 5.7%, this difference is higher than the average growth rate and corresponds to almost two-thirds of a standard deviation. If instead the Creditor Rights index was four (the maximum possible value), then we obtain that $g = -0.009 *$ Median number of Patents in ISIC. Therefore, $g_2 - g_1 = -0.009$. Thus, the more innovative industry had a 0.9% *lower* continuously compounded growth rate compared to the less innovative ISIC industry. So, when we go from a country with Creditor Rights index of 1 to 4, the pattern of growth *reverses* from the more innovative industry growing at two-thirds of a standard deviation more to it growing less than the less innovative industry. Instead, if Creditor Rights index takes the value of three, then $g = 0.006 *$ Median number of Patents in ISIC. Therefore, $g_2 - g_1 = 0.006$. Therefore, when we go from a country with Creditor Rights index of 3 to 1, the difference in growth rates over the period 1978-1992 for two adjacent innovative industries becomes *six times larger*. Clearly, these economic magnitudes are large.

6 Robustness

6.1 The Role of Financial Development

Should we be concerned that the weakness of creditor rights in countries such as the US may be capturing the effect of other relevant cross-country differences, for example, in the level of financial development, which has been argued to boost innovation through greater competition (Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992))? It might be the case that in countries with poorly developed financial markets, creditor rights are designed to be stronger to boost credit and intermediation. Since poor financial development can lead to lower innovation, for example, due to lack of competition, innovation and creditor rights could be negatively related simply due to the omission of financial development in our estimations. While we do employ country dummies throughout, the financial development itself may be time-varying for each country. This, in particular, also raises a potential concern for our tests based on time-series changes in creditor rights: creditor rights may be weakened precisely at the point when financial development reaches high levels, and, in turn, innovation receives a boost.

To address these issues, we employ four measures of financial development: Accounting Standards, Total (stock market) Capitalization to GDP, Domestic Private Credit to GDP, and Private Credit to GDP per capita (from LLSV, 1998 and Rajan and Zingales, 1998). Requiring these variables reduces our sample size to around 40 countries. We estimate the univariate correlation between Creditor Rights and these measures of financial development. The correlation is uniformly negative and of the order of -0.30 to -0.40, confirming that creditor rights and financial development are negatively correlated, but also illustrating that only around 15% of the total variability of creditor rights can be explained by financial development. That is, there is sufficient *exogenous* variation in creditor rights of its own. This is not surprising, for example, given the substantial variation in creditor rights within the G-7 countries which have relatively high levels of financial development.

In Table 11, we consider the role of financial development in the cross-country tests of Tables 3 and 4, controlling for the effect of creditor rights, and importantly, analyzing its interaction with creditor rights. We find in Panel A that financial development is generally positively associated with greater innovation as posited by the theories of endogenous growth. Furthermore, there is some evidence that financial development boosts innovation more so for industries that are technologically more innovative. In Panel B, however, we show that the effect of financial development on innovation is weaker if creditor rights are stronger. The interaction term between financial development and creditor rights is uniformly negative and generally statistically significant. Importantly, in both these tables, the differential effect of creditor rights on industry-level innovation continues to be of economic and statistical importance.

Finally, in Panel C, we employ the triple interaction of financial development, creditor rights, and technological innovation intensity of industries. The interaction is uniformly negative and signifies that creditor rights weaken the effect of financial development, especially so in industries where intrinsic propensity to innovate is higher. We conclude that the effect of bankruptcy codes on innovation is over and above that of financial development, and that well-developed financial markets can boost innovation further if they are combined with bankruptcy codes that are more friendly to firmowners/equityholders and management.

6.2 Alternative Rankings

Note that as in Rajan and Zingales (1998), we are using the innovation intensity of firms in the US as a proxy for the innovation intensity of industries worldwide. However, to account for inter-temporal variations in the innovation intensity of industries due to the arrival of technological shocks through time, we use the one year lagged measure of innovation intensity. However, this results in patents of US firms being included in the left-hand-side and right-hand-side of our regression specifications. While the one-year lagged measure partially mitigates the issue of spurious correlation caused when using the contemporaneous measure, this problem may still exists due to the autoregressive nature of the patents process. This may account for some of our results; therefore, we examine in results that are available on request the robustness of our results to this issue along three different dimensions.

First, we examine the time-series behavior of total number of patents. We find using the de-trended number of patents, the number of patents follows an AR(1) process. Similarly, the number of citations follows the AR(1) process too. Hence, we re-run our specifications by calculating the technological innovation intensity of an industry with two lags of the number of patents of US firms. We find our results are unchanged when we employ the two year lags.

Second, instead of employing the actual level of median patents in a sub-class in the US as a proxy for the sub-class' technological innovation intensity, we employ the contemporaneous rank of sub-class in the US. As argued earlier, the rank ordering of sub-classes is highly correlated across countries. Hence, using the rank itself as a measure of technological innovation intensity alleviates the concern from having a US-based ranking on the right hand side. Again, our results are robust to this choice of ranking. The interaction term of creditor rights and sub-class rank is uniformly negative and significant.

Finally, we employ a partition of industries into above median number of patents and below median number of patents amongst all industries. Again, this has the flavor of not relying excessively on the actual number of patents in the US data, but merely relying on the sort it produces of industries' innovation intensity. As in the case of time-series results in Panel B of Table 8, we find that by and large, increase in creditor rights reduces innovation in both sets of industries, but the effect is much stronger for industries with above median number of patents.

7 Conclusion

Identifying government and private means to promote innovation in economies is considered an important step towards generating sustainable long-run growth rates. In this paper, we developed a theory to show that debtor-friendly bankruptcy codes encourage firm-level innovation by promoting continuations upon failure. Employing industry-level cross-country data, we showed that innovative industries exhibit greater intensity of patent creation, patent citation and faster growth in countries with weaker creditor rights in bankruptcy; this finding is confirmed by within-country analysis that exploits time-series changes in creditor rights; and, finally, weak creditor rights were shown to amplify the effect of financial development on innovation.

On the one hand, these results have important policy implications for the endogenous growth literature in that legal institutions governing financial contracts can play a first-order role in fostering innovation and growth. On the other hand, they suggest an altogether different approach to thinking about the design of bankruptcy codes in a normative sense, in particular, an approach that focuses on the ex-ante real investments undertaken by firms in response to bankruptcy codes rather than on the ex-post efficiency of continuation outcomes when firms are in distress. In addition, the results suggest a promising line of corporate-finance enquiry which examines how multi-national companies organize their innovative and standard operations. For example, do they locate their subsidiaries internationally such that innovative operations are funded under debtor-friendly bankruptcy regimes?

References

[1] Acharya, Viral V., Yakov Amihud, and Lubomir Litov, 2007, "Creditor Rights and Conglomerate Mergers," Working Paper, London Business School.

[2] Acharya, Viral V., Rangarajan K. Sundaram, and Kose John, 2004, "Cross-Country Variations in Capital Structures: The Role of Bankruptcy Codes," Working Paper, London Business School.

[3] Acharya, Viral V., Rong Leng, and Rangarajan K. Sundaram, 2006, "Do Bankruptcy Costs Affect Firm Leverage? Time-series and Cross-country Evidence," Working Paper, London Business School.

[4] Aghion, P. and Howitt, P., 1992, "A Model of Growth Through Creative Destruction," *Econometrica*, 60(2), 323–352.

[5] Albert, M., D. Avery, F. Narin, and P. McAllister, 1991, "Direct validation of citation counts as indicators of industrially important patent," *Research Policy* 20, 251–259.

[6] Allen, Franklin and Douglas Gale, 2000, *Comparing Financial Systems*, Cambridge, MA, MIT Press.

[7] Andrade, Gregor and Steven N. Kaplan, 1998, "How costly is Financial (Not Economic) Distress? Evidence from Highly Levered Transactions that Became Distressed," *Journal of Finance*, Vol. 53, 1443-1491.

[8] Armour, John, Brian R. Cheffins, David A. Skeel, Jr., 2002, "Corporate Ownership Structure and the Evolution of Bankruptcy Law: Lessons from the UK, " Working Paper, Centre for Business Research and Faculty of Law, University of Cambridge.

[9] Baumol, W., 2001, *The free market innovation machine*, Princeton, Princeton University Press.

[10] Bebchuk, Lucian, 2002, "Ex Ante Costs of Violating Absolute Priority in Bankruptcy," 57, *Journal of Finance*, 445-460.

[11] Bertrand, Marianne, and Sendhil Mulainathan, 2003, "Enjoying the Quiet Life? Corporate Governance and Managerial Preferences," *Journal of Political Economy*, 111, 1043–1075.

[12] Bertrand, Marianne, Esther Duflo, and Sendhil Mulainathan, 2004, "How Much Should We Trust Difference-In-Differences Estimates," *Quarterly Journal of Economics*, 119, 249–275.

[13] Chhava, Sudheer and Michael Roberts, 2006, "Is Financial Contracting Costly? An Empirical Analysis of Debt Covenants and Corporate Investment," Working Paper, Wharton School of Business, University of Pennsylvania.

[14] Cockburn, I., and R. Henderson, 1998, "Absorptive Capacity, Coauthoring behavior, and the organization of research in drug discovery," *Journal of Industrial Economics* 46, 157–182.

[15] Cohen, W., Nelson, R. and Walsh, J. 1996, "Appropriability Conditions and Why Firms Patent and Why They do Not in the American Manufacturing Sector," Paper presented at the OECD Conference on New Indicators for the Knowledge-Based Economy.

[16] Dewantripont, Mathias and Tirole, Jean, 1994, "A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence," *Quarterly Journal of Economics* 109, 1027–1054.

[17] Djankov, Simeon, McLiesh, Caralee and Shleifer, Andrei, 2005, "Private Credit in 129 Countries," NBER Working Paper Series, Vol. w11078.

[18] Efrat, Rafael, 1999, "The Transformation of The Israeli Bankruptcy System as a Reflection of Social Changes," *Vanderbilt Journal of Transnational Law.*

[19] Fan, Wei and Michelle J. White, 2003, "Personal Bankruptcy and the Level of Entrepreneurial Activity," *Journal of Law and Economics*, XLVI, 543–567.

[20] Gertner, Robert and David Scharfstein, 1991, "A Theory of Workouts and the Effects of Reorganization Law," *Journal of Finance* 46(4), 1189-1222.

[21] Griliches, Z., A. Pakes, and B. Hall, 1987, "The value of patents as indicators of inventive activity," in P. Dasgupta and P. Stoneman, eds., *Economic Policy and Technological Performance*, Gambridge England: Cambridge University Press.

[22] Griliches, Z., 1990, "Patent statistics as economic indicators: A survey," *Journal of Economic Literature*, 28, 1661–1707.

[23] Grossman, G. and Helpman, E., 1991, "Inovation and Growth in the Global Economy," Cambridge: MIT Press.

[24] Hall, Bronwyn H., Jaffe, Adam B. and Trajtenberg, Manuel, 2001, "Market Value and Patent Citations: A First Look," NBER Working Paper No. W7741.

[25] Hall, B., A. Jaffe, and M. Trajtenberg, 2005, "Market value and patent citations," *RAND Journal of Economics* 32, 101–128.

[26] Haselmaan, Rainer, Katharina Pistor and Vikrant Vig, 2006, "How Law Affects Lending," Working Paper, Columbia Business School.

[27] Hyytinen, Ari, Iikka Kuosa and Tuomas Takalo, 2001, "Law or Finance: Evidence from Finland," Working Paper, The Research Institute of The Finnish Economy.

[28] Kang, Nimrit and Nitin Nayar, 2004, "The Evolution of Corporate Bankruptcy Law in India," 2004, *Money and Finance*, Oct 03 - Mar 04, 37-58.

[29] King, Robert and Ross Levine, "Finance and Growth: Schumpeter Might be Right," 1993, *Quarterly Journal of Economics*, CVIII, 3, 717-738.

[30] Kortum, Samuel and Josh Lerner, "What is behind the recent surge in patenting?" 1999, *Research Policy*, 28, 1-22.

[31] Landier, Augstin, 2006, "Entrepreneurship and the Stigma of Failure," Working Paper, Stern School of Business, New York University.

[32] La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert W. Vishny, 1997, "Legal determinants of external finance," *Journal of Finance*, 52, 1131-1150.

[33] La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert W. Vishny, 1998, "Law and finance," *Journal of Political Economy*, 101, 678-709.

[34] La Porta, Rafael, Florencio Lopez-de-Silanes, and Andrei Shleifer, 1999, "Corporate Ownership Around the World," *Journal of Finance*, vol. 54(2), pages 471-517, 04.

[35] Manso, Gustavo, 2005, "Motivating Innovation," Working Paper, MIT.

[36] Martel, Jocelyn, 1994, "More on the Impact of Bankruptcy Reform in Canada, " Working Paper, Centre interuniversitaire de recherche en analyse des organisations

[37] Modigliani, Franco and Merton H. Miller, 1958, "The costs of capital, corporation finance and the theory of investment," American Economic Review, 48, 261–297.

[38] Nini, Greg, David C. Smith and Amir Sufi, 2006, "Creditor Control Rights and Firm Investment Policy," Working Paper, University of Chicago, Graduate School of Business.

[39] Pakes, A., and M. Shankerman, 1984, "The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources," in Zvi Griliches, ed., *R&D, Patents and Productivity,* University of Chicago Press, 98–112.

[40] Rajan, Raghuram and Luigi Zingales, "What Do We Know about Capital Structure? Some Evidence from International Data," 1995, *Journal of Finance*, vol. 50(5), pages 1421-1460.

[41] Rajan, Raghuram and Luigi Zingales, "Financial dependence and growth," 1998, *American Economic Review*, 88:559–586.

[42] Romer, P., 1986, "Increasing Returns and Long-Rung Growth. Journal of Political Economy," 94(5), 1002–1037.

[43] Sundaram, Rangarajan K., 2003, "Generalized Bandit Problems," Working Paper, Stern School of Business; forthcoming in *Social and Strategic Behavior: Essays in Honor of Jeffrey S. Banks* (David Austen-Smith and John Duggan, Eds).

[44] Trajtenberg, M., 1990, "A penny for your quotes: Patent citations and the value of information," *RAND Journal of Economics*, 21, 325–342.

Appendix 1: Parametric assumptions and proofs

ASSUMPTION 1. The following assumption ensures that the value of the un-levered firm under the Explore strategy, $\overline{V_R}$, is greater than that under the Exploit strategy, $\overline{V_T}$:

$$\gamma q_G > 4\alpha\left(1 + 0.5\bar{l} + 0.5p\right) + 0.5\left(\bar{l} + p\right) \tag{A1}$$

In other words, we assume that the expected cash flows from the Explore strategy when it succeeds are sufficiently higher than the total cash flows from the Exploit strategy. The assumption is a natural one to make given the considerable returns that firms realize from successful innovations.

ASSUMPTION 2. The following assumptions are required for Propositions 1, 2 and 3 to hold:

$$\gamma \geq 2 \text{ and } p \geq 0.5 \tag{A2}$$

In other words, we assume that the cashflows from the Explore strategy are at least twice the cash flows from the Exploit strategy ($\gamma \geq 2$), and the likelihood of success on the less risky Exploit strategy is at least a half.[16]

LEMMA 1*:* If the Exploit strategy was implemented at date 0 and control rests with creditors in bankruptcy, then conditional upon default
(a) Creditors liquidate and this decision is efficient ex-post if $\widetilde{L} = \bar{l}x_1$.
(b) Creditors liquidate and this decision is *inefficient* ex-post if $\widetilde{L} = \underline{l}x_1$ and $\frac{pF}{p+\underline{l}} < x_1 < F$.
(c) Creditors continue and this decision is efficient ex-post if $\widetilde{L} = \underline{l}x_1$ and $\alpha \leq x_1 \leq \frac{pF}{p+\underline{l}}$.

Proof of Lemma 1: First consider $\widetilde{L} = \bar{l}x_1$.

Case 1: $F - x_1 \leq \bar{l}x_1 < x_1 : \min\left(\widetilde{L}, F - x_1\right) = F - x_1 > p\min\left(x_1, F - x_1\right) = p\left(F - x_1\right)$. So, creditors liquidate.

Case 2: $\bar{l}x_1 < F - x_1 \leq x_1 : \min\left(\widetilde{L}, F - x_1\right) = \bar{l}x_1$ while $p\min\left(x_1, F - x_1\right) = p\left(F - x_1\right) \leq px_1$. Since $p < \bar{l}$, creditors liquidate.

Case 3: $\bar{l}x_1 < x_1 < F - x_1 : \min\left(\widetilde{L}, F - x_1\right) = \bar{l}x_1$ while $p\min\left(x_1, F - x_1\right) = px_1$. Since $p < \bar{l}$, creditors liquidate.

Now, consider $\widetilde{L} = \underline{l}x_1$.

Case 1: $F - x_1 \leq \underline{l}x_1 < x_1 : \min\left(\widetilde{L}, F - x_1\right) = F - x_1 > p\min\left(x_1, F - x_1\right) = p\left(F - x_1\right)$. So, creditors liquidate.

Case 2: $\underline{l}x_1 < F - x_1 \leq x_1 : \min\left(\widetilde{L}, F - x_1\right) = \underline{l}x_1$ while $p\min\left(x_1, F - x_1\right) = p\left(F - x_1\right)$. So, creditors liquidate if $x_1 > \frac{pF}{p+\underline{l}}$ and continue if $x_1 \leq \frac{pF}{p+\underline{l}}$.

Case 3: $\underline{l}x_1 < x_1 < F - x_1 : \min\left(\widetilde{L}, F - x_1\right) = \underline{l}x_1$ while $p\min\left(x_1, F - x_1\right) = px_1$. Since $p > \underline{l}$, creditors continue.

[16] In fact, the assumption that p be greater than half is a rather weak sufficient condition. The condition $\bar{l} > 0.265$, meaning that liquidation, when the high liquidation values are realized, provides at least 26.5% of the first period cash flow, suffices. Since the high liquidation value must be higher than the probability of success under the Exploit strategy (p) for liquidations to occur in equilibrium, this assumption holds for even very low probabilities of success with the Exploit strategy.

The result follows by comparing with the first best which is to liquidate when $\widetilde{L} = \bar{l}x_1$ and continue when $\widetilde{L} = \underline{l}x_1$. $\diamondsuit$

LEMMA 2: If the Exploit strategy was implemented at date 0 and control rests with equityholders in bankruptcy, then conditional upon default
(a) Equityholders always continue and this decision is efficient ex-post if $\widetilde{L} = \underline{l}x_1$.
(b) Equityholders continue and this decision is *inefficient* ex-post if $\widetilde{L} = \bar{l}x_1$ and $\frac{F}{2} \leq x_1 \leq \frac{(1-p)F}{1+\bar{l}-2p}$.
(c) Equityholders liquidate and this decision is efficient ex-post if $\widetilde{L} = \bar{l}x_1$, and $\alpha < x_1 < \frac{F}{2}$ or $\frac{(1-p)F}{1+\bar{l}-2p} < x_1 < F$.

Proof of Lemma 2: First consider $\widetilde{L} = \bar{l}x_1$.

Case 1: $F - x_1 \leq \bar{l}x_1 < x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = \bar{l}x_1 - F + x_1$ while $p\max\left(x_1 - F + x_1, 0\right) = p\left(2x_1 - F\right)$. So, equityholders continue if $x_1 \leq \frac{(1-p)F}{1+\bar{l}-2p} < F$ since $\bar{l} < p$.

Case 2: $\bar{l}x_1 < F - x_1 \leq x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = 0 < p\max\left(x_1 - F + x_1, 0\right) = p\left(2x_1 - F\right)$. So, equityholders continue.

Case 3: $\bar{l}x_1 < x_1 < F - x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = 0$ and $p\max\left(x_1 - F + x_1, 0\right) = 0$. Since equityholders are indifferent, they liquidate efficiently.

Now, consider $\widetilde{L} = \underline{l}x_1$.

Case 1: $F - x_1 \leq \underline{l}x_1 < x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = \underline{l}x_1 - F + x_1$ while $p\max\left(x_1 - F + x_1, 0\right) = p\left(2x_1 - F\right)$. Since $\underline{l} < p$ and $x_1 < F$, $p\left(2x_1 - F\right) > \underline{l}x_1 - F + x_1$. Therefore, equityholders continue.

Case 2: $\underline{l}x_1 < F - x_1 \leq x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = 0 < p\max\left(x_1 - F + x_1, 0\right) = p\left(2x_1 - F\right)$. So, equityholders continue.

Case 3: $\underline{l}x_1 < x_1 < F - x_1 : \max\left(\widetilde{L} - F + x_1, 0\right) = 0$ and $p\max\left(x_1 - F + x_1, 0\right) = 0$. Since equityholders are indifferent, they continue efficiently.

The result follows by comparing with the first best which is to liquidate when $\widetilde{L} = \bar{l}x_1$ and continue when $\widetilde{L} = \underline{l}x_1$. $\diamondsuit$

LEMMA 3: If the Explore strategy was implemented at date 0 and control rests with creditors in bankruptcy, then conditional upon default
(a) Creditors liquidate and this decision is efficient ex-post if the signal is bad and $\widetilde{L} = \bar{l}x_2$.
(b) Creditors liquidate and this decision is *inefficient* ex-post in the following three cases: (i) signal is good, $\widetilde{L} = \bar{l}x_2$ and $\frac{q_G F}{q_G + \bar{l}} < x_2 < F$ (ii) signal is good, $\widetilde{L} = \underline{l}x_2$, and $\frac{q_G F}{q_G + \underline{l}} < x_2 < F$ (iii) signal is bad, $\widetilde{L} = \underline{l}x_2$, and $\frac{pF}{p+\underline{l}} < x_2 < F$.
(c) Creditors continue with the Explore strategy and this decision is efficient ex-post in the following two cases: (i) signal is good, $\widetilde{L} = \bar{l}x_2$ and $0 \leq x_2 < \frac{q_G F}{q_G + \bar{l}}$ (ii) signal is good, $\widetilde{L} = \underline{l}x_2$ and $0 \leq x_2 < \frac{q_G F}{q_G + \underline{l}}$.
(d) Creditors continue with the Exploit strategy and this decision is efficient ex-post if signal is bad, $\widetilde{L} = \underline{l}x_2$ and $0 \leq x_2 \leq \frac{pF}{p+\underline{l}}$.

Proof of Lemma 3: We first consider the case when the signal is good. So, the payoff from continuing with the Explore strategy is $q_G \min\left(\gamma x_2, F - x_2\right) \geq p\min\left(x_2, F - x_2\right)$ since $q_G > p$ and $\gamma > 1$. So, creditors always prefer continuing with the Explore strategy to continuing with the Exploit strategy. Now we check the creditors' decision to liquidate versus continuing with the Explore strategy.

Case 1: $F - x_2 \leq \widetilde{L} < \gamma x_2 : \min\left(\widetilde{L}, F - x_2\right) = F - x_2 > q_G \min(\gamma x_2, F - x_2) = q_G (F - x_2)$. So, creditors liquidate.

Case 2: $\widetilde{L} < F - x_2 \leq \gamma x_2 : \min\left(\widetilde{L}, F - x_2\right) = \widetilde{L}$ while $q_G \min(\gamma x_2, F - x_2) = q_G (F - x_2)$. So, creditors liquidate if $x_2 > \frac{q_G F}{q_G + (\widetilde{L}/x_2)}$ and continue if $x_2 \leq \frac{q_G F}{q_G + (\widetilde{L}/x_2)}$.

Case 3: $\widetilde{L} < \gamma x_2 < F - x_2 : \min\left(\widetilde{L}, F - x_2\right) = \widetilde{L}$ while $q_G \min(\gamma x_2, F - x_2) = q_G \gamma x_2$. Since $q_G \gamma > \bar{l}$, creditors continue.

Next consider the case when the signal is bad.

Case 1: $F - x_2 > \gamma x_2 > \widetilde{L}$: Payoff from the new work method is $q_B \min(\gamma x_2, F - x_2) = q_B \gamma x_2 > p \min(x_2, F - x_2) = p x_2$ since $p > \gamma q_B$. So, creditors prefer continuing with the Exploit strategy to continuing with the Explore strategy.

Case 2: $x_2 < F - x_2 \leq \gamma x_2$: Payoff from the Exploit strategy is $p x_2$ while the payoff from the Explore strategy is $q_B (F - x_2) \leq \gamma q_B x_2 < p x_2$ since $p > q_B \gamma$. So, creditors prefer the Exploit strategy.

Case 3: $F - x_2 \leq x_2 < \gamma x_2$. Payoff from Exploit strategy is $p (F - x_2) > q_B (F - x_2)$ which is the payoff from the Explore strategy. This inequality follows from $p > q_B$. So, creditors prefer the Exploit strategy.

Therefore when the signal is bad, creditors always prefer continuing with the Exploit strategy to continuing with the Explore strategy. The decision to liquidate versus continue with the Exploit strategy remains the same as in Lemma 1. $\diamondsuit$

LEMMA 4: If the Explore strategy was implemented at date 0 and control rests with equityholders in bankruptcy, then conditional upon default

(I) If the signal is good, equityholders continue with the Explore strategy and this decision is ex post efficient.

(II) If the signal is bad, then

(a) Equityholders continue with the Explore strategy and this decision is ex post *inefficient* in the following cases: (i) $\widetilde{L} = \underline{l} x_2$ and $\frac{F}{2} \leq x_2 < \frac{(p - q_B)F}{2p - q_B - \gamma q_B}$ (ii) $\widetilde{L} = \bar{l} x_2$, and $\frac{F}{2} \leq x_2 < \frac{(p - q_B)F}{2p - q_B - \gamma q_B}$.

(b) Equityholders continue with the Exploit strategy and this decision is ex post efficient if (i) $\widetilde{L} = \underline{l} x_2$ and $x_2 < \frac{F}{1+\gamma}$ (ii) $\widetilde{L} = \underline{l} x_2$ and $\frac{(p - q_B)F}{2p - q_B - \gamma q_B} \leq x_2 < F$.

(c) Equityholders continue with the Exploit strategy and this decision is ex post *inefficient* if $\widetilde{L} = \bar{l} x_2$ and $\frac{(p - q_B)F}{2p - q_B - \gamma q_B} \leq x_2 < \frac{F(1-p)}{1+\bar{l}-2p}$.

(d) Equityholders liquidate and this decision is ex post efficient if (i) $\widetilde{L} = \bar{l} x_2$ and $x_2 < \frac{F}{1+\gamma}$ (ii) $\widetilde{L} = \bar{l} x_2$, and $\frac{F(1-p)}{1+\bar{l}-2p} \leq x_2 < F$.

Proof of Lemma 4: We first consider the case where the signal is good. Payoff from the Explore strategy is $q_G \max(\gamma x_2 - F + x_2, 0) \geq p \max(x_2 - F + x_2, 0)$ since $q_G > p$ and $\gamma > 1$. Therefore, when the signal is good, equityholders always prefer the Explore strategy to the Exploit strategy. The maximum value from liquidation is $\max\left(\bar{l} x_2 - F + x_2, 0\right)$. Now using $\bar{l} < q_G$ we get $\bar{l} x_2 - F + x_2 - q_G (\gamma x_2 - F + x_2) < (1 - \gamma q_G) x_2 - (1 - q_G) F$. Since $\gamma > 1$ and $x_2 < F$, it follows that $(1 - \gamma q_G) x_2 - (1 - q_G) F < 0$. Therefore, $\bar{l} x_2 - F + x_2 < q_G (\gamma x_2 - F + x_2)$. So, $\max\left(\bar{l} x_2 - F + x_2, 0\right) \leq q_G \max(\gamma x_2 - F + x_2, 0)$. So, equityholders prefer continuing with the Explore strategy to liquidation. Therefore, when the signal is good, equityholders continue with the Explore strategy.

When the signal is bad, payoff from the Explore strategy is $q_B \max(\gamma x_2 - F + x_2, 0)$.

Case 1: $F - x_2 > \gamma x_2 > x_2 > \bar{l} x_2 : q_B \max(\gamma x_2 - F + x_2, 0) = p \max(x_2 - F + x_2, 0) = \max\left(\widetilde{L} - F + x_2, 0\right) = 0$. Therefore, equityholders implement the first best in this case which is to liquidate when $\widetilde{L} = \bar{l} x_2$ and continue with the Exploit strategy when $\widetilde{L} = \underline{l} x_2$.

Case 2: $\bar{l} x_2 < x_2 < F - x_2 \leq \gamma x_2 : p \max(x_2 - F + x_2, 0) = \max\left(\widetilde{L} - F + x_2, 0\right) = 0$. Therefore, equityholders continue with the Explore strategy.

Case 3: $F - x_2 \leq x_2 \leq \gamma x_2 : p \max(x_2 - F + x_2, 0) = p(x_2 - F + x_2)$ and

$q_B \max(\gamma x_2 - F + x_2, 0) = q_B(\gamma x_2 - F + x_2)$. Therefore, equityholders continue with the Explore strategy when $\frac{F}{2} \leq x_2 < F\left(\frac{p-q_B}{p-q_B+p-\gamma q_B}\right)$ and continue with the Exploit strategy when $F\left(\frac{p-q_B}{p-q_B+p-\gamma q_B}\right) \leq x_2 < F$. Using Lemma 2, we know that these strategies are the dominant ones when $\widetilde{L} = \underline{l} x_2$. So, we check for the case when $\widetilde{L} = \bar{l} x_2$.

Sub-case A: $\frac{F}{2} \leq x_2 < F\left(\frac{p-q_B}{p-q_B+p-\gamma q_B}\right)$: If $x_2 \leq \frac{F(1-q_B)}{1+\bar{l}-q_B-\gamma q_B}$, then equityholders continue with the Explore strategy while they liquidate if $x_2 > \frac{F(1-q_B)}{1+\bar{l}-q_B-\gamma q_B}$.

Sub-case B: $F\left(\frac{p-q_B}{p-q_B+p-\gamma q_B}\right) \leq x_2 < F$: If $x_2 \leq \frac{F(1-p)}{1-p+\bar{l}-p}$, then equityholders continue with the Exploit strategy while they liquidate if $x_2 > \frac{F(1-p)}{1-p+\bar{l}-p}$. $\diamondsuit$

Proof of Proposition 1: From Lemma 1, the deadweight costs from bankruptcy when the firm uses the Exploit strategy and when creditors are in control, equal

$$0.5 \int_{\frac{pF}{p+\underline{l}}}^{F} (p x_1 - \underline{l} x_1)\, dx_1 = 0.25\,(p - \underline{l}) \left[1 - \left(\frac{p}{p+\underline{l}}\right)^2\right] F^2 \equiv a_T F^2 ,$$

where

$$a_T \equiv 0.25\,(p - \underline{l}) \left[1 - \left(\frac{p}{p+\underline{l}}\right)^2\right] .$$

From Lemma 2, the deadweight costs from bankruptcy when the firm follows the Exploit strategy and equityholders are in control equals

$$0.5 \int_{\frac{F}{2}}^{\frac{(1-p)F}{1+\bar{l}-2p}} (\bar{l} x_1 - p x_1)\, dx_1 = 0.25\,(\bar{l} - p) \left[\left(\frac{1-p}{1+\bar{l}-2p}\right)^2 - \frac{1}{4}\right] F^2 \equiv b_T F^2$$

where

$$b_T \equiv 0.25\,(\bar{l} - p) \left[\left(\frac{1-p}{1+\bar{l}-2p}\right)^2 - \frac{1}{4}\right] .$$

Similarly, from Lemma 3, the deadweight costs from bankruptcy when the firm follows the

Explore strategy and creditors are in control equal

$$0.25 \int_{\frac{q_G F}{q_G+\bar{l}}}^{F} \left(q_G \gamma x_2 - \bar{l} x_2\right) dx_2 + 0.25 \int_{\frac{q_G F}{q_G+\underline{l}}}^{F} \left(q_G \gamma x_2 - \underline{l} x_2\right) dx_2 + 0.25 \int_{\frac{pF}{p+\underline{l}}}^{F} \left(p x_2 - \underline{l} x_2\right) dx_2$$
$$\equiv \quad a_R F^2$$

where

$$a_R \equiv 0.125 \left\{ \begin{array}{c} \left(\gamma q_G - \bar{l}\right) \left[1 - \left(\frac{q_G}{q_G+\bar{l}}\right)^2\right] + \left(\gamma q_G - \underline{l}\right) \left[1 - \left(\frac{q_G}{q_G+\underline{l}}\right)^2\right] \\ + \left(p - \underline{l}\right) \left[1 - \left(\frac{p}{p+\underline{l}}\right)^2\right] \end{array} \right\} .$$

Finally, from Lemma 4, the deadweight costs from bankruptcy when the firm follows the Explore strategy and equityholders are in control equal

$$0.25 \int_{\frac{F}{2}}^{\frac{(p-q_B)F}{2p-q_B-\gamma q_B}} \left(p x_2 - q_B \gamma x_2\right) dx_2 + 0.25 \int_{\frac{F}{2}}^{\frac{(p-q_B)F}{2p-q_B-\gamma q_B}} \left(\bar{l} x_2 - q_B \gamma x_2\right) dx_2$$
$$+0.25 \int_{\frac{(p-q_B)F}{2p-q_B-\gamma q_B}}^{\frac{F(1-p)}{1+\bar{l}-2p}} \left(\bar{l} x_2 - p x_2\right) dx_2$$
$$\equiv \quad b_R F^2 \ ,$$

where

$$b_R \equiv 0.125 \left\{ \begin{array}{c} \left(p - \gamma q_B\right) \left[\left(\frac{p-q_B}{2p-q_B-\gamma q_B}\right)^2 - \frac{1}{4}\right] + \left(\bar{l} - \gamma q_B\right) \left[\left(\frac{p-q_B}{2p-q_B-\gamma q_B}\right)^2 - \frac{1}{4}\right] \\ + \left(\bar{l} - p\right) \left[\left(\frac{1-p}{1+\bar{l}-2p}\right)^2 - \left(\frac{p-q_B}{2p-q_B-\gamma q_B}\right)^2\right] \end{array} \right\} .$$

We now proceed to prove the results.

(a) From the expressions above, we obtain that

$$8\left(a_R - a_T\right) = \left(\gamma q_G - \bar{l}\right) \left[1 - \left(\frac{q_G}{q_G + \bar{l}}\right)^2\right] + \left(\gamma q_G - \underline{l}\right) \left[1 - \left(\frac{q_G}{q_G + \underline{l}}\right)^2\right] - \left(p - \underline{l}\right) \left[1 - \left(\frac{p}{p + \underline{l}}\right)^2\right] .$$

Because $q_G > \bar{l}$ from (5), it follows that

$$\gamma q_G - \bar{l} > \gamma \bar{l} - \bar{l} \ = \ (\gamma - 1)\, \bar{l} \ .$$

Also, since $p < \bar{l}$ from (5), we obtain that

$$p - \underline{l} < \bar{l} - \underline{l}.$$

In turn, $\gamma q_G - \bar{l} > p - \underline{l}$ because $\gamma > 2$ (by Assumption A2) and $\bar{l} > 0$, and $\underline{l} > 0$.

Next, since $\underline{l} < \bar{l}$, it follows that

$$\gamma q_G - \underline{l} = \gamma q_G - \bar{l} + \bar{l} - \underline{l} > 2\left(p - \underline{l}\right)$$

where we have used the facts $\gamma q_G - \bar{l} > p - \underline{l}$ and $\bar{l} > p$. Since $\bar{l} > \sqrt{\frac{8}{5}} - 1$ (by Assumption A2) and $q_G < 1$, it follows that

$$\frac{q_G}{q_G + \bar{l}} < \sqrt{\frac{5}{8}} \, . \tag{22}$$

Thus,

$$\begin{aligned} 8\left(a_R - a_T\right) &> \left(p - \underline{l}\right)\left[2 - 2\left(\frac{q_G}{q_G + \bar{l}}\right)^2 - \left(\frac{q_G}{q_G + \underline{l}}\right)^2 + \left(\frac{p}{p + \underline{l}}\right)^2\right] \\ &> \left(p - \underline{l}\right)\left[1 - 2\frac{5}{8} + \left(\frac{p}{p + \underline{l}}\right)^2 + 1 - \left(\frac{q_G}{q_G + \underline{l}}\right)^2\right] \\ &= \left(p - \underline{l}\right)\left[\left(\frac{p}{p + \underline{l}}\right)^2 - \frac{1}{4} + 1 - \left(\frac{q_G}{q_G + \underline{l}}\right)^2\right] > 0 \, , \end{aligned}$$

where the last step follows from $\underline{l} < p$. Therefore, $a_R > a_T$. ♢

(b) Similarly, it can be shown that

$$\begin{aligned} 8\left(b_R - b_T\right) &= \left(p - \gamma q_B\right)\left[\left(\frac{p - q_B}{2p - q_B - \gamma q_B}\right)^2 - \frac{1}{4}\right] + \left(\bar{l} - \gamma q_B\right)\left[\left(\frac{p - q_B}{2p - q_B - \gamma q_B}\right)^2 - \frac{1}{4}\right] \\ &\quad + \left(\bar{l} - p\right)\left[\left(\frac{1 - p}{1 + \bar{l} - 2p}\right)^2 - \left(\frac{p - q_B}{2p - q_B - \gamma q_B}\right)^2\right] - 2\left(\bar{l} - p\right)\left[\left(\frac{1 - p}{1 + \bar{l} - 2p}\right)^2 - \frac{1}{4}\right] \\ &= \left(\bar{l} - p\right)\left[\frac{1}{2} - \left(\frac{1 - p}{1 + \bar{l} - 2p}\right)^2 - \left(\frac{p - q_B}{2p - q_B - \gamma q_B}\right)^2\right] \\ &\quad + \left(p + \bar{l} - \gamma q_B\right)\left[\left(\frac{p - q_B}{2p - q_B - \gamma q_B}\right)^2 - \frac{1}{4}\right] \, . \end{aligned}$$

Since $\gamma q_B < p < 2p$, it follows that $\left(\bar{l} - p\right) < \left(p + \bar{l} - \gamma q_B\right)$. Therefore,

$$8\left(b_R - b_T\right) < \left(p + \bar{l} - \gamma q_B\right)\left[\frac{1}{4} - \left(\frac{1 - p}{1 + \bar{l} - 2p}\right)^2\right] < 0 \, ,$$

since $\frac{1-p}{1+\bar{l}-2p} > \frac{1}{2}$. Therefore, $b_R < b_T$. ♢

Proof of Proposition 2: The value of the levered firm can be written in general as (for the Explore strategy with sub-script R on V, a and b, and for the Exploit strategy with sub-script T, and with $c = 1$ for the Explore strategy and $c = 1 + \alpha$ for the Exploit strategy):

$$\begin{aligned} V(F) &= K - a\pi F^2 - b(1-\pi)F^2 \; - 0.5\tau F^2 + cF\tau, \text{ so that} \\ \frac{dV}{dF} &= c\tau - 2a\pi F - 2b(1-\pi)F \; - \tau F, \text{and} \\ \frac{d^2V}{dF^2} &= -2a\pi - 2b(1-\pi) - \tau < 0 \ . \end{aligned} \tag{23}$$

Therefore, setting $\frac{dV}{dF} = 0$, we obtain that optimal leverage and the optimized firm value are given respectively as

$$F^* = \frac{c\tau/2}{0.5\tau + a\pi + b(1-\pi)} \quad \text{and} \quad V^* = K + \frac{c^2\tau^2/4}{0.5\tau + a\pi + b(1-\pi)}$$

Then,

$$\frac{dF^*}{d\pi} = -\frac{(a-b)\,c\,(\tau/2)}{[0.5\tau + a\pi + b(1-\pi)]^2} \quad \text{and} \quad \frac{dV^*}{d\pi} = -\frac{(a-b)\,c^2\left(\tau^2/4\right)}{[0.5\tau + a\pi + b(1-\pi)]^2} \ .$$

Thus, for the Exploit strategy, since $a_T < b_T$ from Proposition 1, we obtain that

$$\frac{dF_T^*}{d\pi} = -\frac{(a_T - b_T)(c_T)(\tau/2)}{[0.5\tau + a_T\pi + b_T(1-\pi)]^2} > 0 \ .$$

Similarly, for the Explore strategy, since $a_R > b_R$,

$$\frac{dF_R^*}{d\pi} = -\frac{(a_R - b_R)(c_R)(\tau/2)}{[0.5\tau + a_R\pi + b_R(1-\pi)]^2} < 0 \ . \diamondsuit$$

Proof of Proposition 3: This follows directly from the expressions for optimized firm value in the proof of Proposition 2 above:

$$\frac{dV_R^*}{d\pi} = -\frac{(a_R - b_R)\left(c_T^2\right)\left(\tau^2/4\right)}{[0.5\tau + a_R\pi + b_R(1-\pi)]^2} < 0 \ , \text{ and}$$

$$\frac{dV_T^*}{d\pi} = -\frac{(a_T - b_T)\left(c_R^2\right)\left(\tau^2/4\right)}{[0.5\tau + a_T\pi + b_T(1-\pi)]^2} > 0 \ . \diamondsuit$$

Figure 1: Correlation between GNP per capita and Aggregate Innovation

The figure plots for each country in our sample the GNP per capita in constant 1994 dollars (from LLSV 1998) and the various measures of innovation in the country. The top-left, top-right, bottom-left and bottom-right panels uses the total number of patents issued by the US Patent Office to firms in the country, the citations to these patents, the number of firms that get issued patents, and the average number of patents issued to such firms, respectively.

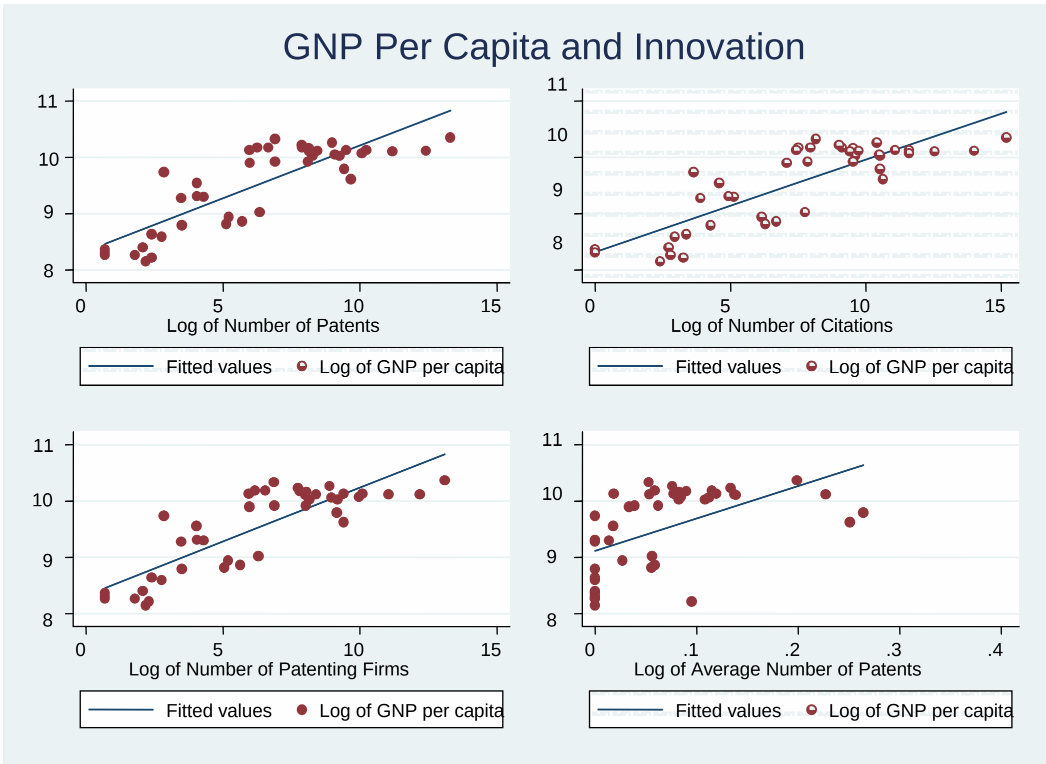
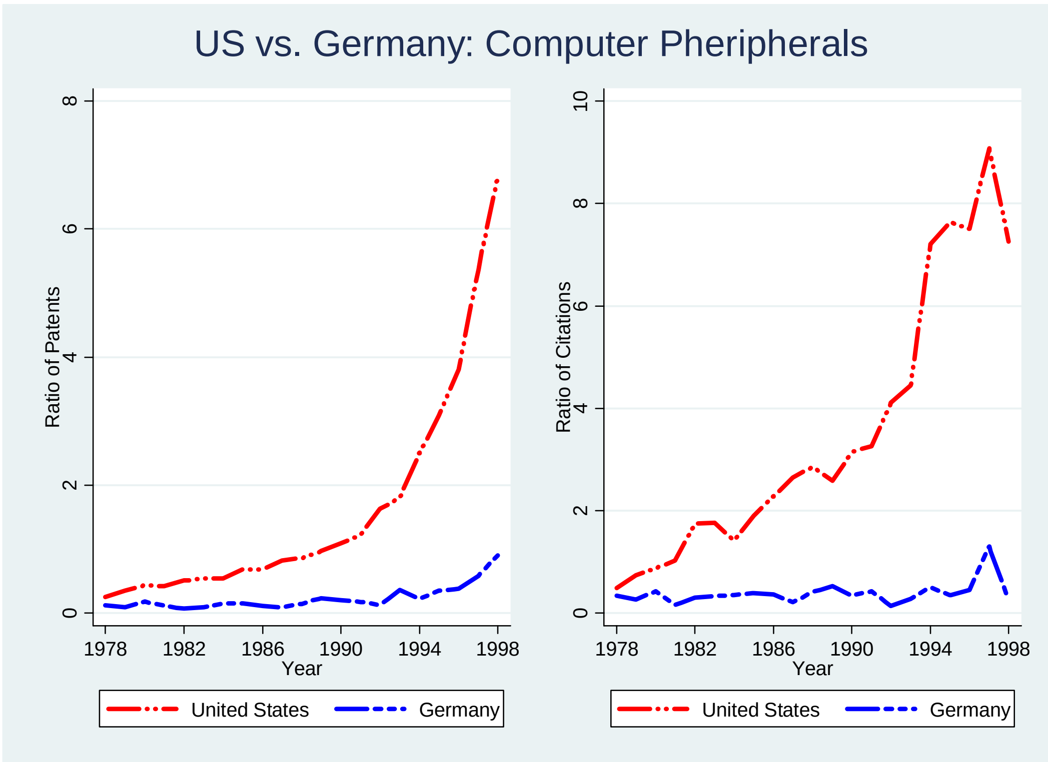
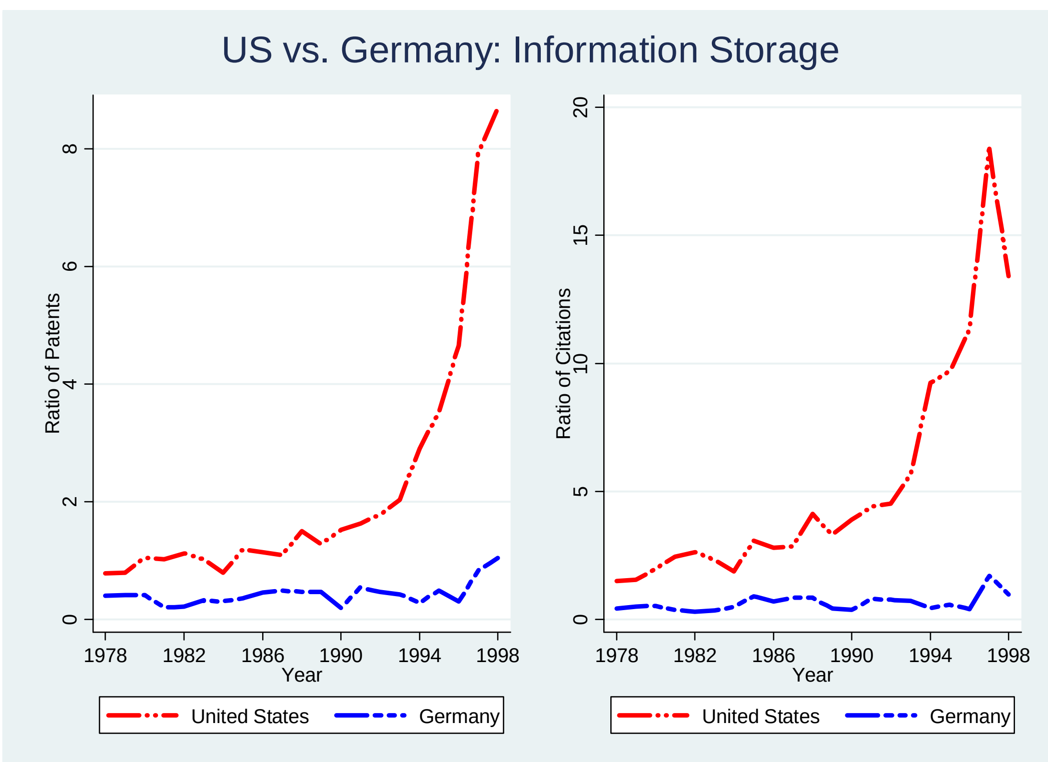
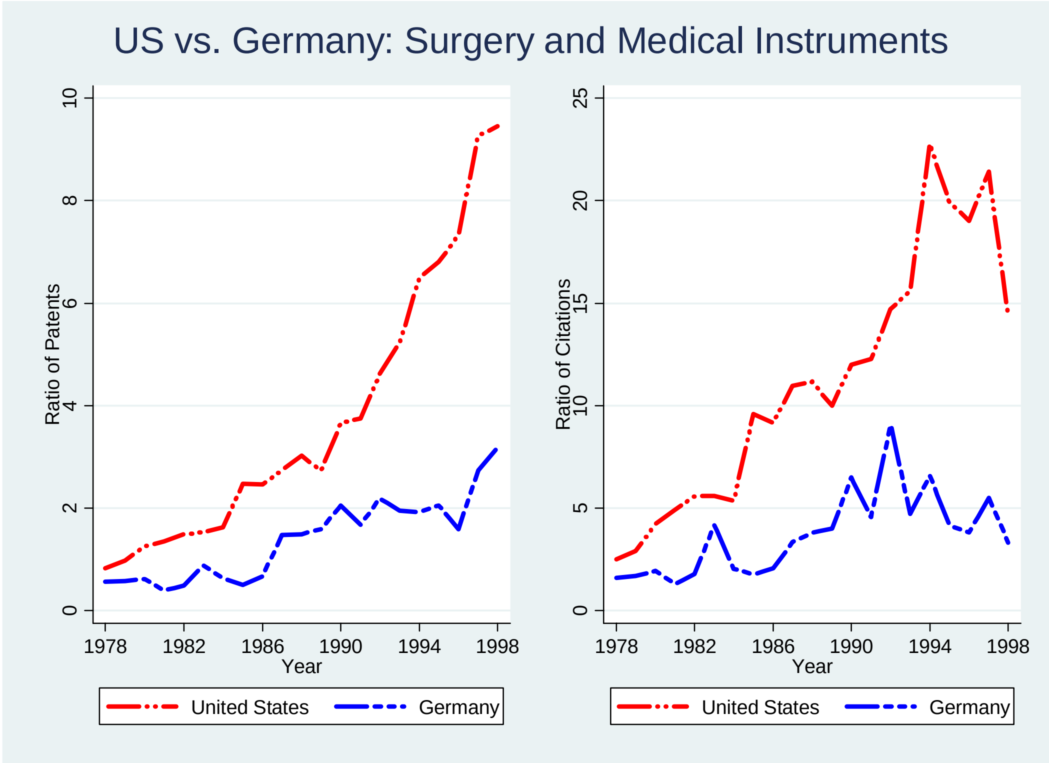


Figure 2: Differences in Innovation between Innovation-intensive and Non-intensive sectors for US and Germany

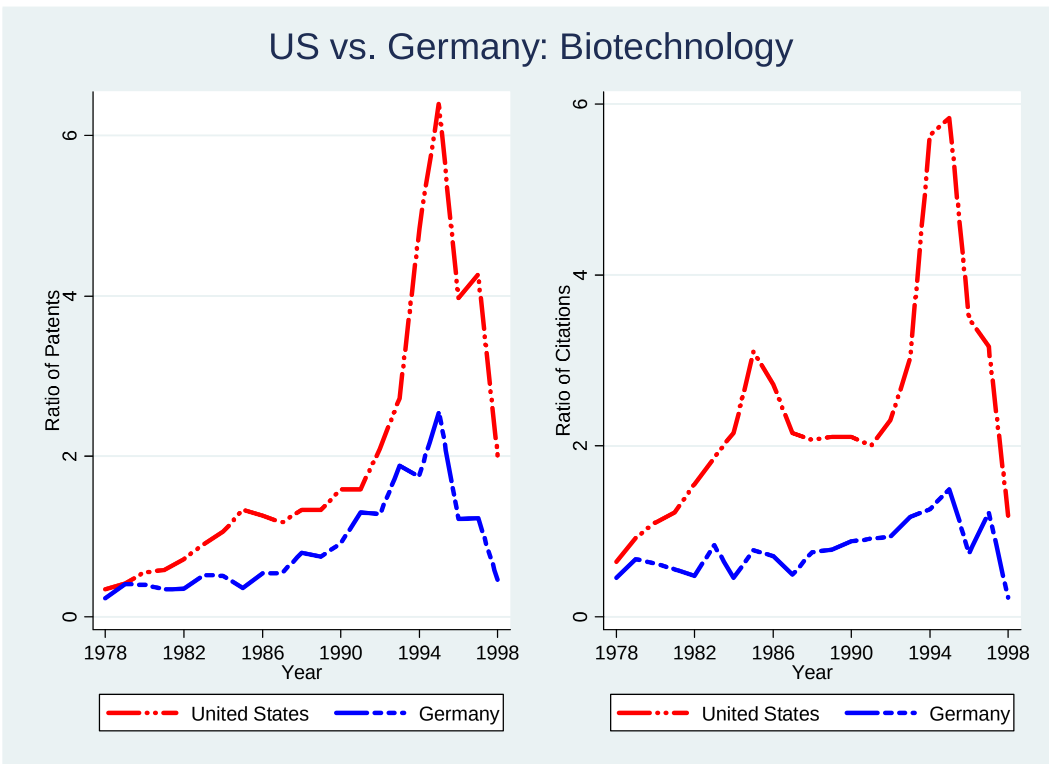
The figures below plot the time series of the *ratio of patents* issued to four Innovation-intensive sectors (2A -Computer Pheripherals, 2B - Information Storage, 2C - Surgery and Medical Instruments, and 2D - Biotechnology) to the patents issued to a non-intensive sector Textiles and Apparel.







US vs. Germany: Surgery and Medical Instruments
Ratio of Patents
Ratio of Citations
Year
United States
Germany



US vs. Germany: Biotechnology
Ratio of Patents
Ratio of Citations
Year
United States
Germany

Figure 3: Timeline of the model

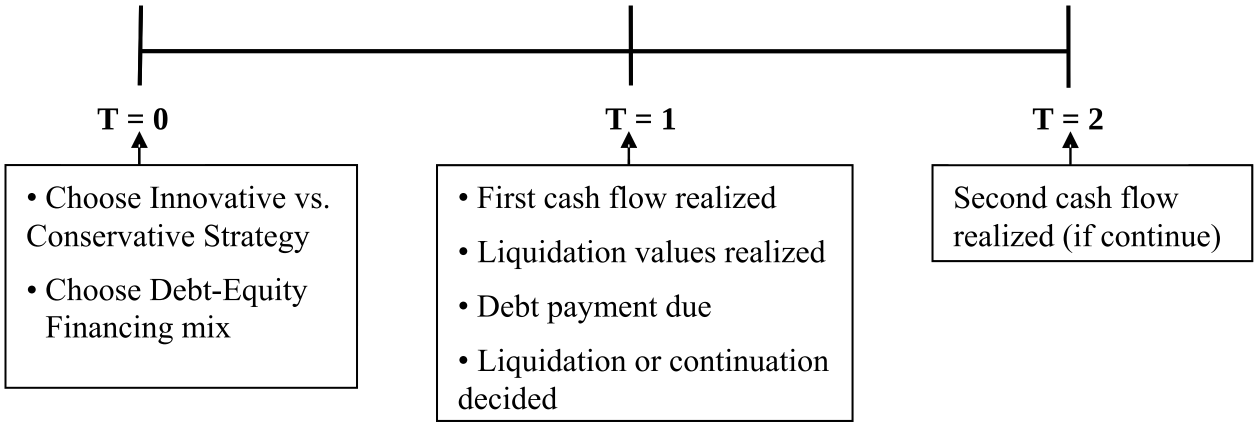


Table 1: Patenting Intensity across Industry Categories

Panel A: Number of patents in an application year (1978-2002)

	USPTO Sub-category	Mean	Median	Std. Devn.	Minimum	Maximum
1	Chemical	4442	4030	1344	1211	6985
2	Computers & Communications	4908	2473	5061	948	16824
3	Drugs & Medical	3616	2360	2927	786	9839
4	Electrical & Electronic	4797	3954	2685	2299	10328
5	Mechanical	3231	2914	1304	1331	5518
6	Others	3510	3243	1260	1285	5876

Panel B: Number of citations to patents in an application year (1978-2002)

	USPTO Sub-category	Mean	Median	Std. Devn.	Minimum	Maximum
1	Chemical	27932	31462	11161	566	39777
2	Computers & Communications	41523	26324	30463	1413	103674
3	Drugs & Medical	27073	25576	16509	600	50922
4	Electrical & Electronic	33090	32951	14842	1919	56160
5	Mechanical	19337	18989	7774	905	29651
6	Others	22601	23589	8816	838	32396

Table 2: Patenting Intensity across Industry Categories for US and Germany

Panel A: Number of patents in an application year (1978-2002) for US and Germany

		Mean		Median		Standard Deviation	
	USPTO Category	Germany	US	Germany	US	Germany	US
1	Chemical	707	4267	669	3988	249	1582
2	Computers & Communications	226	4714	169	2177	183	5049
3	Drugs & Medical	332	3474	280	2270	186	2952
4	Electrical & Electronic	546	4609	474	3595	288	2791
5	Mechanical	626	3104	586	2738	289	1427
6	Others	400	3371	391	3165	161	1415

Panel B: Number of Citations to patents in an application year (1978-2002) for US and Germany

		Mean		Median		Standard Deviation	
	USPTO Category	Germany	US	Germany	US	Germany	US
1	Chemical	2872	25699	3544	30585	1558	13189
2	Computers & Communications	960	38205	997	24019	522	31345
3	Drugs & Medical	1320	24908	1405	20929	743	17492
4	Electrical & Electronic	2071	30448	2374	27798	973	16898
5	Mechanical	2437	17793	2718	18950	1140	9163
6	Others	1607	20794	1822	23338	843	10505

Table 3: Impact of Creditor Rights on the Total Number of Patents

The OLS regressions below implement the following model:

$$y_{ict} = \beta_0 + \beta_1 * \left(CreditorRights_{ct} * PatentIntensity_{it}\right) + \beta_2 * CreditorRights_{ct} + \beta_3 PatentIntensity_{it} + \beta X + \varepsilon_{ict}$$

where y refers to the *logarithm of the number of patents* applied in USPTO patent subclass i, in country c and year t. The sample includes patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). Patent Intensity for USPTO patent subclass i is measured as (a) the median number of patents held by a US firm in patent subclass i, and (b) the average number of patents held by a US firm in patent subclass i. To avoid spurious results, we calculate these measures for the year (t-1). The Creditor Rights index for country c is from DMS (2005) – a higher measure indicates stronger rights provided to creditors in bankruptcy. The control variables include the number of firms in USPTO subclass i; the Legal Origin of country c; industry fixed effects at the level of 36 industry sub-categories constructed by Hall, Jaffe and Trajtenberg (2001) which correspond approximately to the 2-digit SIC level codes; country fixed effects; and dummies for the application years 1978-2002. The Country*Industry fixed effects are included for the developed countries at the level of six industry categories constructed by Hall, Jaffe and Trajtenberg (2001). The Standard errors are adjusted for clustering of residuals by country.[1] *** and ** denote significance at the 1% and 5% levels respectively.

Sample	(1) Full	(2) 1978-1990	(3) 1991-2002	(4) Full	(5) Full	(6) Full	(7) Full	(8) Full	(9) Full	(10) Full	(11) Full
Creditor Rights * Median no. of patents in Subclass	-0.018*** (2.74)	-0.027*** (4.44)	-0.014* (1.68)		-0.026*** (4.03)	-0.026*** (3.69)	-0.018*** (2.74)	-0.026*** (3.69)	-0.026*** (3.74)	-0.025*** (3.45)	-0.024*** (2.63)
Creditor rights	-0.058 (1.11)	-0.037 (0.96)	-0.071 (1.13)	-0.040 (0.99)	0.000 (0.01)	-0.021 (1.09)	-0.058 (1.11)	-0.021 (1.04)	-0.024 (1.24)	0.022** (2.53)	0.023** (2.63)
Median no. of patents in Subclass	0.120*** (10.38)	0.134*** (8.88)	0.120*** (8.71)		0.135*** (7.57)	0.132*** (6.96)	0.120*** (10.38)	0.131*** (6.68)	0.134*** (6.97)	0.130*** (6.17)	0.130*** (6.18)
No. of firms in Subclass					0.254*** (6.36)	0.249*** (6.44)		0.246*** (6.39)	0.246*** (6.32)	0.239*** (6.64)	0.241*** (6.58)
One if English Legal Origin						0.207*** (4.25)		0.213*** (4.20)	0.233*** (4.01)	0.004 (0.29)	-0.002 (0.32)
One if French Legal Origin						-0.008 (0.28)		-0.002 (0.05)	0.011 (0.38)	0.469*** (35.77)	0.477*** (15.69)
One if German Legal Origin						0.232*** (5.09)		0.228*** (5.04)	0.258*** (4.96)	-0.020** (2.06)	0.031*** (41.84)
One if Scandinavian Legal Origin						0.037** (2.23)		0.042** (2.34)	0.053*** (2.84)		
Creditor Rights * Avg. no. of patents in Subclass				-0.032** (2.01)							
Average no. of patents in Subclass				0.220*** (5.52)							
Country Fixed Effects	No	No	No	No	No	No	Yes	No	No	Yes	Yes
Industry Fixed Effects	No	No	No	No	No	No	No	Yes	No	Yes	Yes
Country*Industry Fixed Effects	No	No	No	No	No	No	No	No	No	No	Yes
Year Fixed Effects	No	No	No	No	No	No	No	No	Yes	Yes	No
Observations	517117	200365	304257	517117	517117	517117	517117	516995	517117	516995	514112
Adjusted R-squared	0.02	0.03	0.02	0.04	0.56	0.57	0.58	0.57	0.57	0.58	0.58

[1] In this and the following tables, we estimated each specification with errors clustered by time, industry and country. Since clustering by country generates the largest standard errors, we report them.

Table 4: Impact of Creditor Rights and Total Number of Citations to Patents

The OLS regressions below implement the following model:

$$y_{ict} = \beta_0 + \beta_1 * \left(CreditorRights_{ct} * PatentIntensity_{it}\right) + \beta_2 * CreditorRights_{ct} + \beta_3 PatentIntensity_{it} + \beta X + \varepsilon_{ict}$$

where y refers to the *logarithm of the number of citations to patents* that were applied in USPTO patent subclass i, in country c and year t. The sample includes citations to those patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). Patent Intensity for USPTO patent subclass i is measured as (a) the median number of patents held by a US firm in patent subclass i, and (b) the average number of patents held by a US firm in patent subclass i. To avoid spurious results, we calculate these measures for the year (t-1). The Creditor Rights index for country c is from DMS (2005) – a higher measure indicates stronger rights provided to creditors in bankruptcy. The control variables include the number of firms in USPTO subclass i; the Legal Origin of country c; industry fixed effects at the level of 36 industry sub-categories constructed by Hall, Jaffe and Trajtenberg (2001) which correspond approximately to the 2-digit SIC level codes; country fixed effects; and dummies for the application years 1978-2002. The Country*Industry fixed effects are included for the developed countries at the level of six industry categories constructed by Hall, Jaffe and Trajtenberg (2001). The Standard errors are adjusted for clustering of residuals by country. *** and ** denote significance at the 1% and 5% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Sample	Full	1978-1990	1991-2002	Full	Full	Full	Full	Full	Full	Full	Full
Creditor Rights * Median no. of patents in Subclass	-0.006	-0.010***	0.001		-0.015***	-0.013***	-0.011***	-0.013***	-0.013***	-0.012***	-0.012***
	(1.02)	(4.08)	(0.07)		(4.04)	(2.97)	(2.77)	(2.87)	(3.77)	(2.91)	(2.47)
Creditor rights	-0.141	-0.133	-0.149	-0.121	-0.086	-0.065	0.471*	-0.061	-0.105**	-0.057	0.509**
	(1.48)	(1.41)	(1.52)	(1.49)	(1.12)	(1.05)	(1.98)	(0.98)	(2.34)	(1.52)	(2.02)
Median no. of patents in Subclass	0.069***	0.059***	0.071***		0.086***	0.080***	0.076***	0.085***	0.093***	0.098***	0.081***
	(7.01)	(12.95)	(4.61)		(9.53)	(7.23)	(6.86)	(6.32)	(11.85)	(7.41)	(6.56)
No. of firms in Subclass					0.205***	0.195***	0.185***	0.187***	0.242***	0.228***	0.175***
					(5.84)	(6.33)	(7.53)	(5.98)	(6.78)	(7.38)	(6.81)
One if English Legal Origin						1.052***	0.688	1.080***	0.524***	0.668***	1.607**
						(13.18)	(1.81)	(13.13)	(8.78)	(43.31)	(2.47)
One if French Legal Origin						0.458***	-0.076	0.518***	-0.081	-1.322***	1.492*
						(6.00)	(0.07)	(6.87)	(1.10)	(26.13)	(1.91)
One if German Legal Origin						0.886***	-0.669***	0.895***	0.472***	0.020	0.625**
						(9.40)	(6.50)	(10.53)	(5.26)	(0.53)	(2.29)
One if Scandinavian Legal Origin						0.570***	-0.864***	0.585***	0.162***	0.363***	
						(17.94)	(6.20)	(22.25)	(8.44)	(31.07)	
Creditor Rights * Avg. no. of patents in Subclass				-0.023							
				(1.44)							
Average no. of patents in Subclass				0.130***							
				(3.40)							
Country Fixed Effects	No	No	No	No	No	No	Yes	No	No	Yes	Yes
Industry Fixed Effects	No	No	No	No	No	No	No	Yes	No	Yes	Yes
Country*Industry Fixed Effects	No	No	No	No	No	No	No	No	No	No	Yes
Year Fixed Effects	No	No	No	No	No	No	No	No	Yes	Yes	No
Observations	405382	189418	215390	405382	405382	405382	405382	405336	405382	405336	403802
Adjusted R-squared	0.02	0.02	0.02	0.02	0.13	0.15	0.17	0.17	0.32	0.37	0.18

Table 5: Impact of Creditor Rights on Innovation per Firm

The OLS regressions below implement the following model:

$$y_{ict} = \beta_0 + \beta_1 * \left(CreditorRights_{ct} * PatentIntensity_{it}\right) + \beta_2 * CreditorRights_{ct} + \beta_3 PatentIntensity_{it} + \beta X + \varepsilon_{ict}$$

where y refers to the logarithm of either of the following measures of innovation per firm: (a) median number of patents, (b) average number of patents, (c) median number of citations to patents, and (d) average number of citations to patents applied in USPTO patent subclass i, country c, year t. The sample includes patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). Patent Intensity for USPTO patent subclass i is measured as the median number of patents held by a US firm in patent subclass i. To avoid spurious results, we calculate these measures for the year (t-1). The Creditor Rights index for country c is from DMS (2005) – a higher measure indicates stronger rights provided to creditors in bankruptcy. The control variables include the number of firms in USPTO subclass i; the Legal Origin of country c; industry fixed effects at the level of 36 industry sub-categories constructed by Hall, Jaffe and Trajtenberg (2001) which correspond approximately to the 2-digit SIC level codes; country fixed effects; and dummies for the application years 1978-2002. The Standard errors are adjusted for clustering of residuals by country. *** and ** denote significance at the 1% and 5% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable is log of:	Median patents			Average patents			Median citations			Average citations		
Creditor Rights * Median no. of patents in Subclass	-0.022***	-0.022***	-0.022***	-0.025***	-0.025***	-0.025***	-0.012***	-0.012***	-0.012***	-0.012***	-0.013***	-0.013***
	(3.31)	(3.35)	(3.35)	(3.26)	(3.36)	(3.36)	(4.27)	(4.34)	(4.34)	(2.79)	(3.04)	(3.04)
Creditor rights	0.017**	0.017**	0.017**	0.022**	0.022**	0.022**	-0.050	-0.050	-0.050	-0.056	-0.057	-0.057
	(2.23)	(2.24)	(2.24)	(2.32)	(2.45)	(2.45)	(1.66)	(1.63)	(1.63)	(1.37)	(1.26)	(1.26)
Median no. of patents in Subclass	0.106***	0.106***	0.106***	0.120***	0.120***	0.120***	0.080***	0.080***	0.080***	0.088***	0.090***	0.090***
	(5.74)	(5.75)	(5.75)	(5.70)	(5.69)	(5.69)	(8.98)	(8.95)	(8.95)	(6.54)	(6.48)	(6.48)
Number of Firms in Subclass		-0.006	-0.006		0.081***	0.081***		0.023***	0.023***		0.111***	0.111***
		(0.42)	(0.42)		(4.83)	(4.83)		(4.10)	(4.10)		(7.06)	(7.06)
One if English Legal Origin			0.017			0.017			1.063***			1.887***
			(1.38)			(1.58)			(29.83)			(11.53)
One if French Legal Origin			-0.092***			-0.102***			-0.022			0.290
			(8.53)			(7.18)			(0.41)			(1.88)
One if German Legal Origin			-0.016***			-0.015***			0.025			0.049
			(3.22)			(2.75)			(0.77)			(1.03)
One if Scandinavian Legal Origin			0.039***			0.037***			0.000			0.329***
			(8.22)			(9.02)			(.)			(42.86)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	504512	504512	504512	504512	504512	504512	396295	396295	396295	404762	404762	404762
Adjusted R-squared	0.03	0.03	0.03	0.04	0.07	0.07	0.28	0.28	0.28	0.31	0.31	0.31

Table 6: Impact of Creditor Rights components on Innovation

The OLS regressions below implement the following model:

$$y_{ict} = \beta_0 + \beta_1 * \left(CRightsComponent_{ct} * PatentIntensity_{it}\right) + \beta_2 * CRightsComponent_{ct} + \beta_3 PatentIntensity_{it} + \beta X + \varepsilon_{ict}$$

where y refers to the logarithm of either of the following measures of innovation per firm: (a) total number of patents, (b) total number of citations to patents, (c) median number of patents, and (d) median number of citations to patents applied in USPTO subclass i, in country c, in year t. The sample includes patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). Patent Intensity for USPTO patent subclass i is measured as (a) the median number of patents held by a US firm in patent subclass i, and (b) the average number of patents held by a US firm in patent subclass i. To avoid spurious results, we calculate these measures for the year (t-1). The components of the Creditor Rights index for country c is from DMS (2005). These are dummy variables where a value of 1 indicates that creditors possess that particular right. The control variables include the number of firms in USPTO subclass i; the Legal Origin of country c; industry fixed effects at the level of 36 industry sub-categories constructed by Hall, Jaffe and Trajtenberg (2001) which correspond approximately to the 2-digit SIC level codes; country fixed effects; and dummies for the application years 1978-2002. The Standard errors are adjusted for clustering of residuals by country. *** and ** denote significance at the 1% and 5% levels respectively.

Dependent variable is log of:	(1) Total no. of patents	(2) Total no. of patents	(3) Total no. of patents	(4) Total no. of patents	(5) Total no. of patents	(6) Total no. of citations	(7) Median no. of patents	(8) Median no. of citations
Creditor consent for Reorgn. * Median patents in Subclass	-0.059***				-0.002	-0.030**	0.002	-0.028**
	(2.88)				(0.18)	(2.46)	(0.25)	(2.13)
No Automatic Stay * Median patents in Subclass		-0.060***			-0.034***	-0.017**	-0.018***	-0.007
		(3.49)			(5.82)	(2.47)	(3.94)	(1.60)
Secured Creditors paid first * Median patents in Subclass			0.066***		0.074***	0.034***	0.054***	0.017**
			(3.32)		(6.52)	(4.55)	(5.96)	(2.51)
Mgmt does not manage in Reorgn. * Median patents in Subclass				-0.056***	-0.044***	-0.021***	-0.045***	-0.020***
				(5.07)	(5.59)	(3.01)	(6.14)	(4.38)
Creditor consent for Reorgn.	-0.465***				0.431***	2.355***	0.158***	1.306***
	(6.91)				(5.09)	(14.20)	(4.15)	(11.18)
No Automatic Stay		-0.031***			-0.339***	-0.777***	-0.128***	-0.461***
		(3.04)			(7.64)	(6.71)	(4.50)	(16.73)
Secured Creditors paid first			0.018		-0.083***	2.226***	-0.088***	-0.669***
			(0.57)		(4.86)	(15.33)	(7.22)	(44.53)
Mgmt does not manage in Reorgn.				0.141***	0.159***	-2.292***	0.104***	-1.988***
				(4.69)	(6.78)	(19.12)	(14.46)	(59.33)
Median no. of patents in Subclass	0.089***	0.096***	0.022***	0.109***	0.039***	0.057***	0.037***	0.053***
	(4.50)	(5.23)	(5.47)	(9.72)	(3.87)	(7.88)	(4.70)	(8.26)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	517650	517650	517650	517650	517650	405857	517650	397193
Adjusted R-squared	0.58	0.58	0.58	0.58	0.58	0.37	0.03	0.28

Table 7: Patenting Intensity for "Treatment" Countries

This table shows the number of US patents for each country that underwent a change in its creditor rights during the period 1978-1999. The columns 'Before' and 'After' show the number of patents before the change and after the change, respectively.

Countries that underwent Decreases in Creditor Rights

Country code	Country Name	Year of change
CAX	Canada	1992
FIX	Finland[2]	1993
IDX	Indonesia	1998
IEX	Ireland	1990
ILX	Israel	1995
INX	India	1993
SEX	Sweden	1995

Countries that underwent Increases in Creditor Rights

Country code	Country Name	Year of change
DKX	Denmark	1984
GBX	United Kingdom	1985
LTX	Lithuania	1995
ROX	Romania	1999
RUX	Russian Federation	1994

[2] Finland underwent a two point decrease in its creditor rights while all other countries experienced a one point change.

Table 8: Impact of <u>Changes</u> in Creditor Rights on Innovation

The OLS regressions below estimate the following model:

$$y_{ict} = \beta_0 + \left[\beta_1 + \beta_2\delta_{ct} + \beta_3\delta_c + \beta_4\delta_t\right] * PatentIntensity_{it} + \beta_5\delta_{ct} + \beta X + \varepsilon_{ict}$$

y refers to the logarithm of either the total number of patents or citations to these patents. δ_{ct} is a dummy variable which equals 1 for country c and years t ≥ m+1 (years t < m+1) if a creditor rights reform initiated in year m increased (decreased) the rights provided to creditors. The sample of changes in creditor rights in different countries is from DMS (2005). Thus δ_{ct} captures the *effect of treatment*. δ_c and δ_t correspond to country and year dummies respectively. Treatment Dummy (-2,-1), Treatment Dummy (0) and Treatment Dummy (≥1) are the equivalents of the Treatment Dummy for time periods t ε (m-2,m-1), t = m and t ≥ m+1 respectively. The sample includes patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). Patent Intensity for USPTO patent subclass i is measured as the median number of patents held by a US firm in patent subclass i. To avoid spurious results, we calculate these measures for the year (t-1). The robust standard errors are adjusted for clustering of residuals by country. ***, **,* denote significance at the 1%, 5%, and 10% levels respectively.

Panel A: Effect of Creditor Rights Changes on Differences between industries in Number of Patents and Citations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable is log of:	Total Number of Patents				Total Number of Citations			
Treatment Dummy (δ_{ct}) * Median No. of Patents in Subclass	-0.023*** (2.78)	-0.022** (2.31)	-0.025** (2.25)		-0.010*** (5.06)	-0.024 (1.14)	-0.037* (1.98)	
Treatment Dummy	0.034 (0.57)	0.020* (1.91)	0.031 (0.60)		-0.025 (0.46)	-0.019 (0.62)	-0.043 (0.89)	
Median no. of patents in Subclass	0.098* (1.79)	0.105 (0.570)	0.036 (0.99)	0.048 (1.05)	-2.794*** (18.54)	-1.460 (0.36)	0.163*** (9.56)	0.118 (0.01)
Treatment Dummy (-2,-1) * Median No. of Patents in Subclass				0.006 (0.54)				-0.005 (0.11)
Treatment Dummy (0) * Median No. of Patents in Subclass				-0.017 (1.14)				0.049 (0.76)
Treatment Dummy (≥1) * Median No. of Patents in Subclass				-0.025*** (2.82)				-0.031 (1.15)
Treatment Dummy (-2,-1)				0.051* (1.96)				0.047 (0.67)
Treatment Dummy (0)				0.092*** (2.85)				-0.050 (0.56)
Treatment Dummy (≥1)				0.048** (2.68)				-0.046 (1.63)
One if French Legal Origin			-0.938*** (6.84)	-0.877 (0.01)			0.773*** (6.84)	0.768 (0.58)
One if German Legal Origin			-0.097*** (3.09)	-0.098*** (209.00)			-0.087 (1.48)	-0.089 (0.24)
One if Scandinavian Legal Origin			-0.072*** (3.75)	0.073 (1.67)			-1.533*** (19.00)	-1.541*** (10.33)
One if Socialist Legal Origin			0.056*** (4.08)	0.107 (0.04)			-2.001*** (17.56)	-2.048 (0.02)
Sample	All countries	Exclude US	All countries	All countries	All countries	Exclude US	All countries	All countries
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies * Median no. of patents in Subclass	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies * Median no. of patents in Subclass	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	517772	286511	517772	517772	517772	211216	405903	405903
Adjusted R-squared	0.15	0.12	0.13	0.13	0.24	0.22	0.19	0.19

Panel B: Which Industries' Innovation Intensity is Affected by Changes in Creditor Rights?

Dependent variable is log of:	(1) Total Number of Patents	(2)	(3) Total Number of Citations	(4)
Treatment Dummy (δ_{ct}) * Number of Patents in subclass higher than median	-0.015***	-0.011***	-0.073***	-0.090***
	(4.03)	(4.23)	(7.29)	(8.91)
Treatment Dummy (δ_{ct}) * Number of Patents in subclass lower than median	-0.009**	-0.007**	-0.054***	-0.048***
	(2.02)	(2.35)	(4.28)	(3.84)
No. of firms in Subclass		0.228***		0.217***
		(5.27)		(1.93)
One if English Legal Origin		-0.125***		1.252***
		(33.08)		(33.62)
One if French Legal Origin		-0.135***		0.316***
		(5.25)		(9.77)
One if German Legal Origin		-0.171***		0.187
		(6.83)		(0.00)
Country Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Country Dummies * Number of Patents in subclass higher than median	Yes	Yes	Yes	Yes
Year Dummies * Number of Patents in subclass higher than median	Yes	Yes	Yes	Yes
Observations	512601	512601	402709	397239
Adjusted R-squared	0.22	0.59	0.27	0.37

Table 9: Tests of the Leverage hypothesis (Proposition 2) for G-7 countries

Panel A: Creditor rights for G-7 countries

This table presents the creditor rights ratings abstracted from La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998) paper. A value of 1 indicates that creditors are provided the specific protection by the law

Country	No automatic stay on assets	Secured creditors first paid	Restrictions for going into reorganization	Management does not stay in reorganization	Creditor rights
France	0	0	0	0	0
Canada	0	1	0	0	1
US	0	1	0	0	1
Italy	0	1	1	0	2
Japan	0	1	0	1	2
Germany	1	1	1	0	3
UK	1	1	1	1	4

Panel B: Regression Results for Tests of the Leverage hypothesis

This table shows regression of 6 measures of leverage on creditor score, patenting intensity (number of patents of median firm in the 2-digit SIC industry in the US), and the interaction of creditor score and patenting intensity, and various fixed effects (country, year, and industry by country) and controls (tangibility, profitability, log of sales, and market to book ratio) as well the interaction of control variables with country dummies. The sample period is from 1990-2005.

	Book Debt	Market Debt	All non-equity liabilities	Net Book Debt	Net Market Debt	Net All non-equity liabilities
Creditor Rights	-1.29%	-2.34%	-8.13%	-1.89%	-1.45%	-8.73%
	(0.95)	(1.61)	(3.58)	(0.80)	(0.59)	(2.81)
Patenting intensity at 2-digit SIC level	0.71%	0.52%	0.85%	0.89%	-0.23%	1.07%
	(2.27)	(1.62)	(2.15)	(1.79)	(0.27)	(1.83)
Creditor Rights * Patenting intensity	-0.59%	-0.43%	-0.71%	-0.81%	-0.34%	-0.95%
	(2.99)	(2.21)	(2.96)	(2.79)	(1.04)	(2.75)
Constant	7.02%	20.22%	47.46%	-13.53%	-6.97%	26.01%
	(1.65)	(4.43)	(6.52)	(1.75)	(0.85)	(2.53)
Observations	60680	60669	60674	60696	60685	60696
R-squared	20%	26%	28%	29%	13%	30%
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry *country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Other characteristics*country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 10: The Effect of Creditor Rights and Innovation Intensity on Growth

The dependent variable in the regressions below is the continuously compounded growth rate in either the Valued Added or the Real Value Added for the period 1978 – 1992 for each ISIC industry in each country. The Creditor Rights index for a country is from DMS (2005) – a higher measure indicates stronger rights provided to creditors in bankruptcy. The median number of patents issued to US firms in each ISIC industry is calculated from the USPTO patent data constructed by Hall, Jaffe and Trajtenberg (2001). The measure of External dependence for each ISIC industry is from Rajan and Zingales (1998). We use the following proxies for Financial Development: (1) Accounting Standards is an Index created by Center for International Financial Analysis & Research examining and rating companies' 1990 annual reports on their inclusion or omission of 90 items from LLSV (1998), (2) Total Capitalization to GDP is the ratio of the sum of equity market capitalization (as reported by the IFC) and domestic credit (IFS line 32a-32f but not 32e) to GDP from Rajan and Zingales (1998), (3) Domestic Private credit to GDP is the ratio of domestic credit to the private sector, which is from IFS line 32d, over GDP from Rajan and Zingales (1998), (4) Log Private Credit to GDP per capita is the logarithm of the ratio of Domestic private credit (IFS line 32d) to the GDP per capita from LLSV(1998). The control variables include the Legal Origin of a country; industry fixed effects at the level of each ISIC and each country. The Standard errors are adjusted for clustering of residuals by country. ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

Dependent Variable is:	(1) Value Added	(2) Real Value Added	(3) Value Added	(4) Real Value Added	(5) Value Added	(6) Real Value Added
Creditor Rights * Median number of patents in ISIC	-0.012***	-0.013***	-0.014***	-0.016***	-0.013**	-0.015***
	(2.59)	(2.86)	(2.87)	(3.34)	(2.55)	(2.89)
Creditor Rights	0.014**	0.016***	0.017***	0.019***	0.016***	0.018***
	(2.48)	(2.67)	(2.85)	(3.16)	(2.68)	(2.88)
Median number of patents in ISIC	0.040**	0.031**	0.040***	0.040**	0.044***	0.051***
	(2.36)	(2.17)	(2.67)	(2.36)	(2.86)	(3.37)
One if English legal origin	0.023***	-0.024***	0.016**	-0.016*	0.015**	-0.015*
	(3.08)	(2.65)	(2.34)	(1.93)	(2.06)	(1.92)
One if German legal origin	-0.014	-0.055***	0.046***	0.076***	0.042***	0.073***
	(1.01)	(3.89)	(4.07)	(6.81)	(3.72)	(6.56)
One if French legal origin	0.369***	-0.011	-0.018**	-0.044***	-0.020**	-0.045***
	(23.23)	(0.76)	(2.21)	(5.19)	(2.37)	(5.31)
Accounting Standards			-0.000	-0.001***	-0.000	-0.001***
			(0.15)	(4.81)	(0.58)	(4.75)
Total Capitalization to GDP			-0.002	0.067***	-0.007	0.061***
			(0.24)	(8.83)	(0.83)	(7.28)
Log of private credit to GDP per capita			-0.202***	-0.022***	-0.197***	-0.019**
			(22.74)	(2.80)	(20.45)	(2.07)
Accounting Standards * External Dependence					0.001	0.001
					(1.26)	(1.20)
Total Capitalization to GDP * External Dependence					0.004	0.003
					(0.28)	(0.18)
Domestic Credit to GDP * External Dependence					-0.028**	-0.022*
					(2.31)	(1.84)
Log of private credit to GDP per capita * External Dependence					0.064**	0.062**
					(2.30)	(2.28)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	589	590	386	387	386	387
Adjusted R-squared	0.93	0.62	0.95	0.62	0.95	0.63

Table 11: The Effect of Financial Development on Innovation Intensity and its Interaction with Creditor Rights

The OLS regressions below add the following interactions to the basic model examined in Tables 3-6: (a) interaction of measures of Financial development with patenting intensity, (b) interaction of measures of Financial development with Creditor Rights, and (c) the triple interaction between measures of Financial development, patenting intensity, and creditor rights. We use the following proxies for Financial Development: (1) Accounting Standards is an Index created by Center for International Financial Analysis & Research examining and rating companies' 1990 annual reports on their inclusion or omission of 90 items from LLSV (1998), (2) Total Capitalization to GDP is the ratio of the sum of equity market capitalization (as reported by the IFC) and domestic credit (IFS line 32a-32f but not 32e) to GDP from Rajan and Zingales (1998), (3) Domestic Private credit to GDP is the ratio of domestic credit to the private sector, which is from IFS line 32d, over GDP from Rajan and Zingales (1998), (4) Log Private Credit to GDP per capita is the logarithm of the ratio of Domestic private credit (IFS line 32d) to the GDP per capita from LLSV(1998). The dependent variable in the regressions is the total number of patents or the total number of citations to these patents applied in USPTO patent subclass i, country c, year t. The sample includes patents issued by the USPTO to US and foreign firms over the period 1978-2002 as constructed by Hall, Jaffe and Trajtenberg (2001). The Creditor Rights index for country c is from DMS (2005) – a higher measure indicates stronger rights provided to creditors in bankruptcy. The Standard errors are adjusted for clustering of residuals by country. *** and ** denote significance at the 1% and 5% levels respectively.

Panel A: The direct and cross-industry effect of Financial Development

Dependent Variable is log of:	Total Number of Patents				Total Number of Citations			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Which Financial Development measure?	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita
Financial Development Measure * Median no. of patents in Subclass	0.002	0.091***	0.096**	0.097***	0.004*	0.036**	0.030	0.046
	(1.42)	(4.63)	(2.27)	(3.55)	(1.82)	(2.09)	(1.06)	(1.41)
Financial Development Measure	-0.002	0.203***	0.331***	0.126	0.008	0.761***	0.930***	0.681***
	(0.74)	(4.45)	(5.39)	(1.45)	(0.90)	(11.85)	(3.81)	(3.95)
Creditor Rights * Median no. of patents in Subclass	-0.023***	-0.014***	-0.019***	-0.018***	-0.008	-0.007**	-0.010***	-0.009
	(3.39)	(3.23)	(2.90)	(2.88)	(0.89)	(2.04)	(3.02)	(1.39)
Creditor rights	-0.004	0.013	0.012	0.005	-0.070	-0.021	-0.048	-0.038
	(0.14)	(0.93)	(0.95)	(0.23)	(0.93)	(1.08)	(1.22)	(0.66)
Median no. of patents in Subclass	0.016	-0.007	0.045	0.097***	-0.172	0.021	0.052*	0.062***
	(0.18)	(0.21)	(1.07)	(6.02)	(1.17)	(0.71)	(1.78)	(3.26)
No. of firms in Subclass	0.254***	0.244***	0.245***	0.250***	0.205***	0.186***	0.190***	0.197***
	(6.32)	(6.73)	(6.72)	(6.26)	(5.81)	(7.58)	(7.03)	(6.09)
Observations	515642	500425	500425	515642	404728	394770	394770	404728
Adjusted R-squared	0.56	0.57	0.57	0.56	0.13	0.16	0.15	0.14

Panel B: The interaction effect of Financial Development and Creditor Rights

Dependent Variable is log of:	Total Number of Patents				Total Number of Citations			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Which Financial Development measure?	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita
Creditor Rights * Financial Development Measure	-0.004	0.004	-0.099*	-0.182***	-0.011	-0.057	-0.397***	-0.522***
	(1.61)	(0.12)	(1.97)	(3.07)	(1.00)	(0.89)	(3.94)	(4.16)
Financial Development Measure	0.008	0.196**	0.549***	0.375***	0.036	0.846***	1.821***	1.420***
	(1.07)	(2.66)	(4.31)	(3.27)	(1.07)	(6.95)	(8.70)	(7.01)
Financial Development Measure * Median no. of patents in Subclass	0.002	0.091***	0.098**	0.098***	0.004**	0.037**	0.039	0.045
	(1.53)	(4.63)	(2.31)	(3.81)	(2.03)	(2.19)	(1.35)	(1.29)
Creditor Rights * Median no. of patents in Subclass	-0.023***	-0.014***	-0.018***	-0.017***	-0.007	-0.007**	-0.008**	-0.008
	(3.32)	(3.19)	(2.76)	(2.84)	(0.80)	(2.08)	(2.44)	(1.23)
Creditor rights	0.300	0.008	0.083***	0.028	0.714	0.044	0.245***	0.030
	(1.55)	(0.23)	(3.64)	(1.63)	(0.87)	(0.63)	(5.57)	(0.63)
Median no. of patents in Subclass	0.003	-0.007	0.042	0.096***	-0.194	0.020	0.040	0.060***
	(0.04)	(0.21)	(1.00)	(6.11)	(1.34)	(0.69)	(1.45)	(3.06)
No. of firms in Subclass	0.253***	0.244***	0.244***	0.249***	0.204***	0.185***	0.187***	0.193***
	(6.34)	(6.72)	(6.70)	(6.36)	(5.88)	(7.56)	(7.26)	(6.46)
Observations	515642	500425	500425	515642	404728	394770	394770	404728
Adjusted R-squared	0.56	0.57	0.57	0.57	0.13	0.16	0.15	0.15

Panel C: The cross-industry interaction effect of Financial Development and Creditor Rights

Dependent variable is log of:	Total Number of Patents				Total Number of Citations			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Which Financial Development measure?	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita	Accounting standards.	Total Capitalization to GDP	Domestic Private Credit to GDP	Log Private Credit to GDP per capita
Creditor Rights * Financial Development Measure * Median no. of patents in subclass	-0.001 (1.21)	-0.038*** (7.29)	-0.078*** (6.01)	-0.073*** (5.10)	-0.004* (1.82)	-0.012** (2.53)	-0.029** (2.35)	-0.038 (1.36)
Financial Development Measure * Median no. of patents in Subclass	0.005 (1.41)	0.152*** (13.72)	0.280*** (5.90)	0.205*** (7.17)	0.014** (2.04)	0.056** (2.66)	0.106** (2.16)	0.101 (1.53)
Financial Development Measure	0.005 (0.92)	0.128* (1.73)	0.345** (2.58)	0.256** (2.31)	0.024 (0.83)	0.824*** (6.88)	1.745*** (8.14)	1.356*** (7.30)
Creditor Rights * Median no. of patents in Subclass	0.069 (0.87)	0.030*** (5.94)	0.041*** (3.78)	-0.006 (1.40)	0.281* (1.73)	0.008 (0.97)	0.014 (1.32)	-0.001 (0.15)
Creditor Rights * Financial Development Measure	-0.003* (1.75)	0.047 (1.45)	-0.012 (0.25)	-0.101* (1.83)	-0.007 (0.69)	-0.043 (0.68)	-0.365*** (3.71)	-0.479*** (4.38)
Creditor rights	0.197 (1.66)	-0.041 (1.35)	0.017 (0.69)	0.015 (0.85)	0.392 (0.56)	0.028 (0.40)	0.221*** (4.88)	0.023 (0.52)
Median no. of patents in Subclass	-0.227 (0.88)	-0.081*** (4.69)	-0.104** (2.47)	0.074*** (8.18)	-0.920* (1.86)	-0.005 (0.13)	-0.015 (0.35)	0.048* (1.92)
No. of firms in Subclass	0.253*** (6.34)	0.244*** (6.72)	0.244*** (6.70)	0.249*** (6.36)	0.204*** (5.88)	0.185*** (7.56)	0.187*** (7.26)	0.193*** (6.46)
Observations	515642	500425	500425	515642	404728	394770	394770	404728
Adjusted R-squared	0.56	0.57	0.57	0.57	0.13	0.16	0.15	0.15