Financial Structures, Intellectual Property Rights, and the Composition of Innovation

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Abstract

This thesis examines how financial development and intellectual property rights (IPR) jointly shape the composition of innovation. Despite the central role of technological progress in Schumpeterian growth models, the global surge in patenting has not produced commensurate productivity gains, a phenomenon known as the "patent puzzle." Using OECD Patent Quality Indicators and cross-country panel data, I estimate two-way fixed effects models linking average patent quality and patent intensity to distinct financing channels and IPR strength. The results show that equity market depth is positively associated with innovation quality, but the marginal effect of stronger patent protection declines as financial markets deepen and may become negative in highly developed systems. A supplementary probability model of breakthrough (top 1% cited) patent intensity further supports this association. Bank-based finance appears more closely associated with patent quantity than quality, though results of the Bank-based and Entrepreneurial-based channels remain less robust and compelling relative to the Market-Based results. These findings suggest that financial structure and legal institutions influence not only how much innovation occurs, but whether it reflects frontier-expanding technological progress.

1 Introduction

For adherents of endogenous growth theory, long-run prosperity is propelled by ground-breaking technologies that alter production, reshape markets, and expand what societies can achieve [Romer, 1990, Aghion and Howitt, 1992]. From the combustion engine and the printing press to the CPU and contemporary large language models, technological progress has repeatedly driven sustained economic growth. Endogenous growth theory formalized this intuition by placing innovation at the center of the growth process. Yet we still understand far less about the conditions that give rise to genuinely transformative innovations, rather than incremental, or low value additions to the technological frontier

A central challenge is measurement. Traditional proxies for innovation such as patent counts or R&D expenditure perform poorly in capturing economically meaningful technological progress. The "patent puzzle" illustrates this tension: global patenting and R&D spending have risen substantially, yet productivity growth in many advanced economies has stagnated [Boldrin and Levine, 2013]. This disconnect suggests that the quantity of innovation tells us little about its economic significance. A more informative measure lies in innovation quality, understood as the technological and economic value embedded in inventive output. A growing literature develops patent-level indicators to capture this dimension, drawing on patent-level micro data to infer quality from the structure of citation networks and disclosure characteristics [Squicciarini et al., 2013, Trajtenberg et al., 1997, Lanjouw and Schankerman, 2004, Hall et al., 2005, Kogan et al., 2017]. While no single indicator is definitive, as each captures a distinct facet of quality, composite measures combining these dimensions provide a more robust proxy for meaningful innovation than raw patent counts or R&D expenditure

Once innovation quality can be measured and compared across countries and over time, we can ask a deeper question: under what institutional and financial environments do high-quality innovations arise, and when do economies instead produce more patents, but not better ones? A revolutionary technology begins as an idea in a human mind, but its realization depends on a complicated ecosystem of incentives, financing, and legal institutions. On the financing side, firms require external capital to transform ideas into marketable technologies. Banks, public equity markets, and venture capital each provide distinct screening mechanisms, risk tolerances, and monitoring structures. Relationship lending can enable firms to leverage intellectual property as collateral [Mann, 2018], yet banks may end up financing patent portfolios optimized for borrowing rather than innovations with real technological value. Public equity markets can aggregate dispersed information and reward high-growth firms [Fama, 1970], but they may also respond to scale, momentum, or hype rather than underlying technological quality. Venture capital, with its high risk tolerance and active governance, may identify frontier innovators, but high-profile failures highlight its limits.

Legal institutions shape incentives alongside financial structure. Strong intellectual property rights (IPR) grant temporary monopoly profits in exchange for disclosure, but they also generate tradeoffs between patenting and secrecy [Klein, 2020]. When protection is strong, firms may choose patenting over secrecy, increasing disclosure and potential spillovers. When protection is weak, firms may rely more heavily on secrecy, limiting diffusion. Stronger formal protection does not necessarily imply socially optimal innovation. Patents can facilitate productive disclosure, but they can also support strategic fencing, defensive accumulation, or rent-seeking behavior. The net effect of IPR on innovation quality may therefore depend on the broader financial environment.

Recent theoretical work emphasizes precisely this interaction. In a Schumpeterian framework with financial frictions, Klein and Yang [2025] show that the growth effects of patent protection depend on financial development: when financial markets are shallow and frictions severe, stronger patent rights can stimulate growth by easing financing constraints; when markets are deep, the marginal growth benefits of stronger protection diminish. Similarly, Maskus et al. [2019] provide empirical evidence that patent protection stimulates R&D primarily in financially underdeveloped economies, suggesting that strong IPR can partially substitute for weak financial systems. However, much of the existing cross-country evidence evaluates innovation using qualitative measures, with the composition of innovation across the quality distribution remaining less explored.

This thesis seeks to contribute to a wider understanding of how economies can foster the kinds of transformative technologies that drive long-run growth. Using OECD Patent Quality Indicators and cross-country panel data, I estimate two-way fixed effects models linking patent quantity and patent quality to distinct financing channels, IPR strength, and their interaction. The central empirical result concerns equity market development. Deeper equity markets are positively associated with higher patent quality. At the same time, the marginal effect of stronger patent rights on quality declines as market depth increases. This interaction remains statistically robust across specifications and survives incremental inclusion of controls. In financially shallower systems, stronger IPR is associated with improvements in patent quality. In financially deeper systems, the same strengthening of patent protection yields smaller, and in some specifications negative, effects on quality. By contrast, bank-based financial development exhibits weaker and less stable relationships with quality and is more consistently associated with patent quantity rather than quality.

These findings support a compositional interpretation of innovation. Financial systems and patent regimes jointly influence whether inventive activity concentrates in higher-quality, productivity-enhancing innovation or expands primarily along the extensive margin through lower-value patent proliferation. To further examine frontier innovation, I estimate zero-inflated negative binomial models of breakthrough patents (top 1% quality). The distribution of breakthrough counts exhibits substantial overdispersion and excess zeros, motivating a framework that distinguishes between structural non-participation in frontier innovation and the intensity of breakthrough production conditional on participation. These supplementary models reinforce the view that financial and legal regimes shape not only the volume of innovation, but its allocation across the quality spectrum.

The rest of the analysis proceeds as follows: # Literature Review ## Innovation and Endogenous Growth

Endogenous growth theory places innovation at the core of long-run economic development. In the canonical models of Romer [1990] and Aghion and Howitt [1992], technological progress arises from intentional R&D investment and creative destruction. Firms innovate to obtain temporary monopoly profits, and the pace of innovation determines sustained productivity growth. These frameworks emphasize that incentives, market structure, and institutional environments shape innovative effort.

However, these models typically treat innovation as homogeneous. In practice, innovations differ widely in technological significance and economic value. Some inventions fundamentally shift production frontiers, while others represent incremental improvements or strategic extensions of existing technologies. The distinction between high-quality, frontier-expanding innovation and lower-value or defensive patenting becomes especially important in light of the patent puzzle: patenting and R&D expenditure have increased substantially, yet productivity growth has not followed proportionally [Boldrin and Levine, 2013]. Understanding growth therefore requires not only measuring the volume of innovation, but examining its composition.

1.1 Measuring Innovation Quality

Because innovation quality is not easily observable, researchers rely on patent-based indicators to approximate technological and economic value. Forward citations capture the extent to which subsequent inventions build upon a given patent, serving as a proxy for technological influence [Hall et al., 2005, Trajtenberg et al., 1997]. Patent family size and the number of claims reflect the private value that firms attribute to their inventions [Lanjouw and Schankerman, 2004]. Measures of originality and generality capture technological breadth and cross-field impact, while citations to non-patent literature indicate scientific relevance [Squicciarini et al., 2013].

Building on Lanjouw and Schankerman [2004], Squicciarini et al. [2013] propose composite indices, that, when aggregated allow cross country and inter temporal comparison. Compared to raw quantity measures, these composite indicators provide a richer representation of whether innovative activity reflects frontier technological progress or incremental patent accumulation.

1.2 Finance and Innovation

A substantial literature examines how financial development affects innovation and growth. Financial intermediaries and markets alleviate credit constraints, mobilize savings, and allocate capital toward productive investment [Levine, 2005]. Because R&D is risky, intangible, and difficult to collateralize, innovative firms may be especially sensitive to financing conditions [Hall and Lerner, 2010].

Different financing channels provide distinct forms of support. Relationship-based bank lending can reduce information asymmetries and enable firms to leverage intangible assets such as patents as collateral [Mann, 2018]. Public equity markets may facilitate risk-sharing and price discovery, potentially rewarding high-growth and high-risk projects [Hall et al., 2005]. Venture capital combines funding with active governance and screening, often targeting early-stage, high-growth firms [Lerner and Nanda, 2020].

At the same time, financial development may alter the type of innovation pursued. Bank-based systems may favor safer, incremental innovation consistent with stable repayment. Equity markets, while potentially supportive of high-growth firms, may also respond to speculative dynamics or short-term performance pressures. These institutional differences suggest that financial structure may shape not only the quantity of innovation, but its allocation across the quality distribution.

1.3 Intellectual Property Rights and Financial Development

Intellectual property rights influence innovation incentives by granting temporary monopoly protection in exchange for disclosure. Stronger patent protection can increase expected returns to innovation, but may also generate distortions through strategic patenting, rent-seeking, or reduced competition. Cross-country variation in IPR strength has therefore become central to empirical analysis.

The Park Index provides a standardized measure of statutory patent protection across countries, capturing dimensions such as coverage, enforcement, and duration [Park, 2008]. Empirical evidence on the relationship between IPR and innovation, however, remains mixed. Stronger patent protection may stimulate R&D in some contexts while yielding limited or even negative welfare effects in others.

Recent work emphasizes the interaction between patent protection and financial development. In a Schumpeterian model with financial frictions, Klein and Yang [2025] demonstrate that the growth effects of stronger patent protection depend critically on financial depth. When financial markets are underdeveloped and frictions severe, stronger IPR can ease financing constraints and stimulate growth. As financial markets deepen and frictions decline, the marginal growth benefits of stronger patent protection diminish.

Similarly, Maskus et al. [2019] provide empirical evidence that patent protection increases R&D investment primarily in countries with relatively low levels of financial development. Their results suggest that strong IPR can partially compensate for weak financial systems by enhancing firms' ability to secure external finance. In financially advanced economies, by contrast, the incremental impact of stronger patent protection appears smaller.

Despite this progress, most cross-country studies focus on aggregate patent counts, R&D spending, or growth outcomes. Much less attention has been paid to how financial structure and IPR regimes jointly shape the quality of innovation. If stronger patent protection in financially developed systems primarily encourages incremental or defensive patenting, aggregate increases in patenting may mask shifts toward lower-value innovation. Conversely, in financially constrained environments, stronger IPR may facilitate access to capital for more transformative projects.

2 Empirical Framework

2.1 Motivation and Overview

This section outlines the empirical strategy used to examine how financial structure and intellectual property institutions jointly shape innovative outcomes. The central objective is to distinguish between the volume of innovation and its composition, particularly with respect to patent quality and breakthrough activity.

Innovation is inherently multi-dimensional. Aggregate patent counts conflate incremental and frontier innovation, while average quality measures can obscure the skewed distribution of technological importance. A small fraction of patents accounts for a disproportionate share of long-run technological progress, yet most country-year observations record no breakthrough innovations at all. Empirically capturing this distributional structure requires moving beyond linear specifications.

The analysis proceeds in two stages. First, I estimate two-way fixed effects (TWFE) panel regressions relating financial development, intellectual property protection, and their interaction to measures of average patent quality and patent quantity. These models exploit within-country variation over time while controlling for unobserved time-invariant heterogeneity and global shocks.

They establish the baseline relationships and reveal systematic differences across financial channels.

Second, because frontier innovation is rare and highly concentrated, I explicitly model breakthrough activity using zero-inflated negative binomial (ZINB) models (add the Long citation). This framework distinguishes between (i) the probability that a country is structurally unlikely to produce frontier innovation and (ii) the intensity of breakthrough production conditional on participation. Together, these approaches allow the analysis to address the central question of the thesis: Do financial structure and patent institutions shape not only how much innovation occurs, but whether it reflects high-quality, frontier-expanding technological progress?

2.2 Baseline Two-Way Fixed Effects Model

The baseline specification estimates the relationship between financial development, intellectual property rights, and innovation outcomes using a two-way fixed effects panel model:

$$Y_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 IPR^c_{it} + \beta_3 (FD_{it} \times IPR^c_{it}) + \mathbf{X}'_{it}\beta + \alpha_i + \lambda_t + \varepsilon_{it} \tag{1}$$

where Y_{it} denotes either: Average patent quality (OECD composite index), or Log patents per 1,000 researchers. FD_{it} measures financial development and is alternately defined as: Log stock market capitalization to GDP (market-based finance), Log domestic bank credit to GDP (bank-based finance), or Log venture capital investment. IPR^c_{it} is the Park index of patent protection [Park, 2008]. $\mathbf{X}_{it}$ includes controls for income per capita, trade openness, R&D intensity, and tertiary education attainment. Country fixed effects α_i absorb time-invariant characteristics. Year fixed effects λ_t capture global shocks. Standard errors are clustered at the country level.

The coefficient of primary interest is β_3, which captures how the marginal effect of patent protection varies with financial development. The marginal effect of IPR on innovation is:

$$\frac{\partial Y_{it}}{\partial IPR_{it}} = \beta_2 + \beta_3 FD_{it}$$

A negative β_3 implies that the impact of stronger patent protection declines as financial markets deepen. This interaction is central to the compositional interpretation developed in the Results section.

The TWFE specification isolates within-country changes over time. Consequently, the estimated relationships reflect how shifts in financial depth and IPR strength within a country are associated with changes in innovation outcomes, rather than cross-country level differences.

2.3 Modeling Frontier Innovation: Zero-Inflated Negative Binomial

Following a standard Zero-Inflated Negative Binomial (ZINB) framework [UCLA Statistical Consulting Group, n.d., Long, 1997], the model is estimated in two parts. The selection margin models the log-odds of being a structural non-innovator, and the intensity margin models the expected breakthrough count μ_{it} via a log-link function, incorporating total patenting as an exposure offset.

Breakthrough innovation exhibits two defining features: extreme overdispersion and excess zeros. The variance of breakthrough counts substantially exceeds the mean, invalidating a Poisson assumption, and a large fraction of country-year observations record zero breakthroughs. These zeros likely reflect a mixture of structural incapacity and stochastic variation.

2.4 Selection Equation

The zero-inflation component, which models the log-odds π_{it} of a country being a "structural non-innovator" in a given year, is specified using a logit link function:

$$\ln\left(\frac{\pi_{it}}{1-\pi_{it}}\right) = \gamma_0 + \gamma_1 \ln(\text{GDP per capita}_{it}) \tag{2}$$

where π_{it} denotes the probability that country i in year t is in the zero-generating state. Higher income levels are expected to reduce this probability, reflecting greater absorptive capacity and technological infrastructure. Negative coefficients in this equation indicate a lower likelihood of structural exclusion from frontier innovation.

2.5 Intensity (Breakthroughs per Patent)

Conditional on being capable of producing breakthroughs, the expected number of breakthrough patents μ_{it} follows a negative binomial process with a log link function:

$$\ln(\mu_{it}) = \beta_0 + \beta_1 FD^c_{it} + \beta_2 IPR^c_{it} + \beta_3(FD^c_{it} \times IPR^c_{it}) + \mathbf{X}'_{it}\beta + \ln(\text{Patents}_{it}) \tag{3}$$

where μ_{it} represents the expected count of breakthrough patents. The term $\ln(\text{Patents}_{it})$ enters as an offset, effectively modeling the rate of breakthrough production. This ensures that the model estimates breakthrough intensity relative to the total patenting volume rather than raw counts.

Because fixed effects are incompatible with zero-inflated models, these ZINB specifications are estimated without country and year fixed effects. They are therefore interpreted as supplementary robustness analyses rather than causal estimates.

3 Data

3.1 Patent Data and Innovation Measures

The core innovation measures in this thesis are derived from the OECD Patent Quality Indicators database [Squicciarini et al., 2013]. The dataset provides patent-level indicators constructed from the EPO's PATSTAT, harmonized across countries and technology classes. This analysis uses the *Patent Quality Index 4*, constructed as an unweighted average of a patent's forward citations (5 years), Family Size, Claims, and Generality.

The primary dependent variable in the baseline analysis is average patent quality at the country-year level, constructed as the mean of the OECD composite quality index (scaled 0-100) across patents filed by inventors residing in a given country in year t. This measure captures the average technological significance of inventive output.

To contrast quality with scale, I also construct a measure of patent quantity, defined as patents per 1,000 researchers and expressed in logarithmic form. Normalizing by researchers mitigates size effects and better reflects innovative intensity rather than population scale.

In addition to average quality, I employ a measure of breakthrough innovation. Following the classification of Ahuja and Lampert [2001], breakthrough patents are defined as those in the top 1% of citation distribution within their technology class and application year. These are aggregated to the country-year level to obtain breakthrough counts. Because breakthrough activity is highly skewed and frequently zero, it is analyzed separately using zero-inflated negative binomial models.

3.2 Financial Development

Financial development is measured along three distinct channels to capture differences in institutional structure:

- Market-based finance: Log stock market capitalization to GDP [World Bank, 2025].
- Bank-based finance: Log domestic credit to the private sector as a share of GDP [World Bank, 2025].
- Venture capital: Log venture capital investment, measured in constant dollars [OECD, 2025].

These measures capture the relative depth and activity of equity markets, traditional banking systems, and risk-oriented entrepreneurial finance, respectively. Each channel is entered separately in baseline specifications to isolate its distinct association with innovation outcomes.

3.3 Intellectual Property Rights

Intellectual property protection is measured using the Park Index [Park, 2008], a widely used cross-country indicator of statutory patent protection strength. The index aggregates five dimensions of patent law, including coverage, duration, enforcement mechanisms, and international treaty membership. Higher values indicate stronger formal protection.

While the index captures legal design rather than enforcement outcomes or litigation intensity, it provides a consistent measure of cross-country variation in patent regimes over time. The Park Index is also mean-centered before interacting with financial variables, and interpolated via a 5-year fill.

3.4 Control Variables

To isolate the relationship between financial structure, IPR, and innovation, the baseline regressions include standard macroeconomic controls:

- Log GDP per capita (constant dollars), capturing income level and absorptive capacity.
- Trade openness (exports plus imports as a share of GDP), capturing exposure to global markets.
- Log R&D expenditure as a share of GDP, capturing innovative input intensity.
- Log tertiary education attainment, capturing human capital.

These variables are commonly used in cross-country innovation and growth regressions and account for factors that may jointly influence financial development and innovative performance [World Bank, 2025].

3.5 Descriptive Patterns

The data reveal several facts that motivate the empirical strategy. First, patent quality and patent quantity are only weakly correlated across country-years, suggesting that scale and value capture distinct dimensions of innovation (see Figure A.5). Second, breakthrough counts exhibit substantial overdispersion: the variance far exceeds the mean, and a large fraction of country-year observations record zero breakthroughs. These features justify modeling quality separately from quantity and motivate the use of ZINB specifications for frontier innovation. Descriptive statistics for all primary variables are provided in Table A.1 in the Appendix.

4 Results

4.1 Market-Based Finance and Patent Quality

I begin with the baseline two-way fixed effects estimates linking market-based financial development, intellectual property protection, and patent quality. Table 1 reports results for the specification in equation (1), incrementally introducing controls while retaining country and year fixed effects.

Table 1: Market Finance and Patent Quality

	Dependent variable:				
	Patent Quality				
	(1)	(2)	(3)	(4)	(5)
Market Cap	0.390	0.364	0.390	0.975^{**}	0.602
	(0.281)	(0.300)	(0.316)	(0.396)	(0.632)
IPR Strength	1.751^{*}	2.036^{**}	2.068^{**}	4.285^{**}	3.859^{***}
	(0.907)	(0.937)	(0.952)	(1.946)	(1.214)
Market Cap × IPR	-0.651^{***}	-0.676^{***}	-0.685^{***}	-1.168^{***}	-1.053^{**}
	(0.229)	(0.232)	(0.232)	(0.394)	(0.430)
GDP per Capita (log)		−0.788	−0.837	-2.337^{*}	−0.819
		(1.821)	(1.856)	(1.386)	(1.678)
Trade Openness			−0.443	−0.515	−1.299
			(1.273)	(1.834)	(1.900)
R&D Expenditure				−0.432	−1.372
				(1.615)	(2.344)
Tertiary Education					-1.244^{*}
					(0.754)
Observations	1,431	1,422	1,422	880	636
R^2	0.020	0.023	0.023	0.025	0.015
Adjusted R^2	−0.048	−0.045	−0.046	−0.069	−0.121
Note:	*p<0.1; **p<0.05; ***p<0.01				
	Country & Year FE included. Clustered SE in parentheses.				

Across specifications, stock market depth is positively associated with average patent quality. In column (4), the coefficient on log market capitalization remains positive and statistically significant. Evaluated at the sample mean of IPR strength, a one standard deviation increase in market depth (approximately one log point) is associated with roughly a one-point increase in the patent quality index. This magnitude is economically meaningful given the relatively tight distribution of average quality across advanced economies.

Stronger patent protection, measured by the Park Index, is also positively associated with patent quality when evaluated at average levels of financial development. However, the central result concerns the interaction between market finance and IPR strength. The coefficient on the interaction term is negative and statistically significant across specifications. Because $\beta_3 < 0$, the marginal effect of stronger patent protection declines as market depth increases. Formally,

$$\frac{\partial Y_{it}}{\partial IPR_{it}} = \beta_2 + \beta_3 FD_{it}$$

The marginal effect of stronger IPR on patent quality declines with financial market depth. The implied turning point occurs at $\ln(\text{Market Finance}_{it}) \approx 3.66$. Given that the sample mean is approximately 3.76, this threshold lies very close to the center of the observed distribution rather than in the extreme tail. In other words, the reversal occurs at typical levels of financial development in advanced economies. For countries below this threshold, stronger patent protection is associated with higher average patent quality. For countries above it, stronger patent protection is associated with lower average quality. The interaction remains robust to incremental controls, and a joint Wald test rejects the null that the financial depth and interaction terms are jointly zero ($p = 0.0032$).

Importantly, these estimates reflect within-country changes over time. The results therefore capture how shifts in financial structure and patent protection within a country are associated with changes in the quality of its innovative output. The relatively modest within R^2 values are typical in fixed-effects panel models, which rely exclusively on within-country variation rather than cross-sectional differences.

Figure 1 illustrates the interaction graphically, plotting predicted patent quality across levels of IPR at low and high levels of market development.

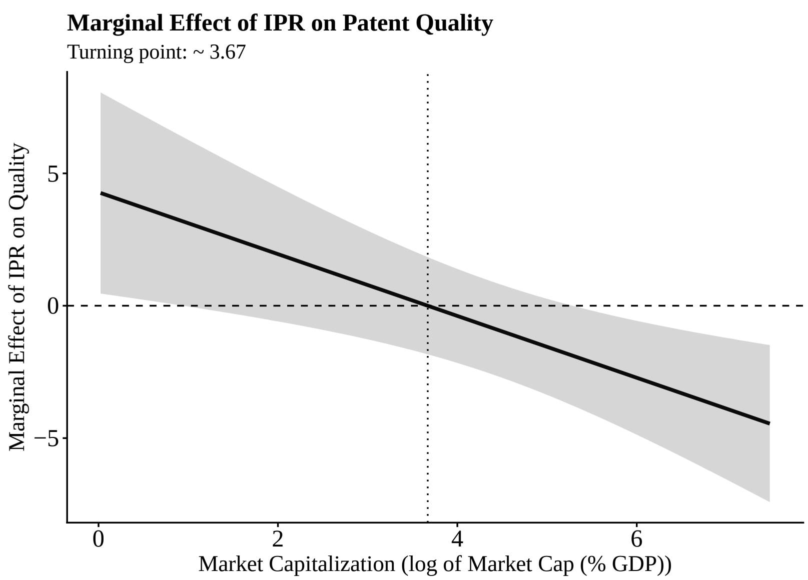

Figure 1: Marginal Effect of Market Finance on Quality at Different IPR Levels

Together, these results suggest that equity market development and patent protection do not operate independently. In financially constrained environments, stronger IPR may improve access to external finance and support higher-quality innovation. In financially mature systems, however, stronger patent protection appears to shift inventive activity toward lower-marginal-value patents, reducing average quality even as overall patenting remains high. The effect is compositional rather than purely scale-driven.

4.2 Bank-Based Finance and Patent Quality

Table 2 presents analogous estimates replacing market capitalization with bank credit.

Table 2: Bank Finance and Patent Quality

	Dependent variable:				
	Patent Quality				
	(1)	(2)	(3)	(4)	(5)
Bank Credit	-1.162^{*}	-0.989	-0.910	0.213	-0.397
	(0.705)	(0.752)	(0.710)	(0.766)	(0.884)
IPR Strength	-1.297	-1.065	-1.907	5.569^{**}	3.667
	(2.874)	(2.993)	(3.376)	(2.283)	(2.758)
Bank Credit × IPR	0.481	0.446	0.648	-1.236^{**}	-0.722
	(0.888)	(0.834)	(0.915)	(0.538)	(0.698)
GDP per Capita (log)		-0.693	-0.988	-1.668	-1.655
		(2.532)	(2.356)	(1.089)	(1.021)
Trade Openness			3.016	-0.447	-1.335
			(1.946)	(1.236)	(1.526)
R&D Expenditure				1.487	2.405
				(1.412)	(1.894)
Tertiary Education					-0.594
					(0.889)
Observations	1,329	1,308	1,302	920	723
R^2	0.010	0.008	0.019	0.017	0.012
Adjusted R^2	-0.067	-0.069	-0.060	-0.075	-0.111
Note:	*p<0.1; **p<0.05; ***p<0.01				
	Country & Year FE included. Clustered SE in parentheses.				

In contrast to the market-based results, the relationship between bank finance and patent quality is weaker and less stable. Coefficients on bank credit vary across specifications and are not consistently distinguishable from zero. The interaction between bank finance and IPR strength does not display the same sign stability observed for market-based finance, and economic magnitudes are small relative to those estimated for equity markets.

These patterns suggest that bank-based financial development does not exhibit a systematic association with shifts in average innovation quality. One interpretation is consistent with theories of relationship lending and collateral-based finance: banks may be well-suited to funding incremental innovation with predictable returns, but less effective at channeling resources toward frontier projects that raise the upper tail of the quality distribution. While banks play a critical role in overall economic activity, the evidence here does not indicate that deeper banking systems are strongly associated with improvements in patent quality.

4.3 Venture Capital and Patent Quality

Estimates using venture capital investment as the financial channel are reported in Table A.2 (see Appendix). The sample size is smaller due to data availability constraints.

The coefficients on venture capital and its interaction with IPR are not consistently statistically significant and exhibit sensitivity to controls. While venture capital is often linked to high-growth entrepreneurial firms at the micro level, the cross-country aggregate variation captured in this panel does not reveal a stable relationship between overall VC investment and average patent quality.

The results across financial channels indicate that the most robust and economically meaningful association with patent quality emerges for market-based finance, particularly through its interaction with patent protection.

4.4 Innovation Quantity

To distinguish composition from scale, I next examine patent quantity per researcher as the dependent variable. Tables 3 and A.2 report the corresponding TWFE estimates.

Table 3: Market Finance and Patent Quantity

	Dependent variable:				
	Log Patents				
	(1)	(2)	(3)	(4)	(5)
Market Cap	0.077	−0.023	−0.019	−0.027	0.124
	(0.079)	(0.102)	(0.100)	(0.095)	(0.157)
IPR Strength	−0.073	−0.207	−0.205	−0.246	−0.383
	(0.246)	(0.266)	(0.263)	(0.260)	(0.356)
Market Cap × IPR	0.060	0.065	0.064	0.076	0.086
	(0.081)	(0.077)	(0.075)	(0.066)	(0.103)
GDP per Capita (log)		0.968	0.955	0.989*	0.759
		(0.635)	(0.607)	(0.601)	(0.576)
Trade Openness			−0.039	−0.028	−0.298
			(0.313)	(0.320)	(0.408)
R&D Expenditure				−0.240	−0.798
				(0.649)	(0.524)
Tertiary Education					0.759***
					(0.258)
Observations	756	754	754	754	533
R^2	0.017	0.070	0.070	0.072	0.243
Adjusted R^2	−0.088	−0.030	−0.031	−0.031	0.121

Note: *p<0.1; **p<0.05; ***p<0.01
Country & Year FE included. Clustered SE in parentheses.

For market-based finance, neither the main effect nor the interaction with IPR displays the same consistent and economically meaningful pattern observed for patent quality. The interaction between equity market depth and patent protection that appears prominently in the quality regressions does not replicate for patent quantity.

For bank-based finance, some specifications show a positive interaction between bank credit and IPR for patent quantity. This pattern contrasts with the quality results and suggests that stronger patent protection in bank-oriented systems may expand patenting activity along the extensive margin without necessarily increasing average technological value.

Venture capital exhibits a negative association with patent quantity in some specifications, though these estimates are sensitive to controls and sample size and should be interpreted cautiously.

The key implication is that financial structure and patent protection affect different dimensions of innovation differently. The strongest and most stable interaction appears for patent quality rather than patent quantity, supporting a compositional interpretation of innovation rather than a purely scale-based one.

Figure A.5 illustrates the weak relationship between patent quantity and average quality across country-years, reinforcing the importance of distinguishing between these two margins.

4.5 Frontier Innovation: Breakthrough Patents

While average quality captures shifts in the distribution of innovation, breakthrough patents represent the upper tail of technological significance. Breakthrough counts exhibit substantial overdispersion and excess zeros, motivating the ZINB framework described in Section 3.

Table 4: ZINB: Market Finance and Breakthroughs

Intensity: Negative Binomial Count	Model 1	Model 2	Model 3	Model 4
Intercept (Count)	-9.415***	-9.275***	-9.801***	-9.515***
	(0.761)	(0.732)	(0.802)	(0.988)
IPR Strength	-0.457***	-0.523***	-0.539***	-0.611***
	(0.062)	(0.062)	(0.148)	(0.182)
Market Cap	-0.064	-0.014	0.206	0.085
	(0.051)	(0.052)	(0.166)	(0.201)
Market Cap × IPR	0.215***	0.160**	-0.024	0.098
	(0.061)	(0.062)	(0.176)	(0.218)
GDP per Capita	0.372***	0.485***	0.399***	0.196*
	(0.074)	(0.074)	(0.090)	(0.106)
Trade Openness		-0.310***	-0.178**	0.051
		(0.051)	(0.077)	(0.111)
R&D Expenditure			0.756***	0.836***
			(0.160)	(0.180)
Tertiary Education				0.175
				(0.161)
Log Theta	0.491***	0.616***	0.750***	0.782***
	(0.079)	(0.085)	(0.106)	(0.131)
Selection: Logit Structural Zero	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Intercept (Zero)	12.733**	12.296*	15.356	15.713
	(5.280)	(7.049)	(19.037)	(14.055)
GDP per Capita (Selection)	-1.820**	-1.819*	-2.334	-2.307
	(0.709)	(0.972)	(2.734)	(1.993)
Num.Obs.	1450	1450	890	641

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Standard errors in parentheses.

Log Theta represents the natural logarithm of the negative binomial dispersion parameter, estimated directly.

Table 4 presents the ZINB estimates decomposing breakthrough innovation into a selection margin (structural non-participation) and an intensity margin (breakthrough production conditional on participation).

In the negative binomial (intensity) equation, the coefficient on IPR strength is negative in several specifications. Interpreted in percentage terms, a one-unit increase in IPR strength corresponds to a reduction in expected breakthrough intensity, holding other variables constant. Exponentiating the coefficient implies that stronger patent protection is associated with a meaningful decline in frontier breakthrough output per patent: a one-unit increase in IPR reduces breakthrough intensity by ~37%. This result is consistent with the possibility that stronger formal protection can encourage strategic patenting or rent-seeking behavior rather than genuine technological advances.

The interaction between market development and IPR in the intensity equation further suggests that the relationship between patent protection and frontier innovation varies with financial depth, consistent with the mechanism identified in the TWFE quality regressions.

The selection equation shows that higher income per capita significantly reduces the probability of structural non-participation in frontier innovation. Economically, this implies that richer economies are substantially less likely to be in a regime where breakthrough innovation is absent, consistent with absorptive capacity, research infrastructure, and human capital explanations.

Because these ZINB models do not include country and year fixed effects, they are interpreted as complementary rather than causal within-country estimates. Still, they complement the central finding: financial and legal regimes shape innovation across the quality spectrum, including the upper tail of breakthrough activity.

5 Summary and Final Thoughts

A Appendix: Supplementary Tables and Figures

A.1 Supplementary Specifications

Baseline Two-Way Fixed Effects (TWFE):

$$Y_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 IPR_{it} + \beta_3 (FD_{it} \times IPR_{it}) + \mathbf{X}'_{it}\beta + \alpha_i + \lambda_t + \varepsilon_{it} \tag{1}$$

ZINB Selection Equation (Structural Zeros):

$$\ln\left(\frac{\pi_{it}}{1-\pi_{it}}\right) = \gamma_0 + \gamma_1 \ln(\text{GDP per capita}_{it}) \tag{2}$$

ZINB Intensity Equation (Count Margin):

$$\ln(\mu_{it}) = \beta_0 + \beta_1 FD_{it} + \beta_2 IPR_{it} + \beta_3 (FD_{it} \times IPR_{it}) + \mathbf{X}'it\beta + \ln(\text{Patents}_{it}) \tag{3}$$

A.2 Supplementary Tables

Table A.1: Descriptive Statistics

Variable	Unique	Missing %	Mean	SD	Min	Median	Max
Breakthrough Count	99	0	4.85	20.96	0.00	0.00	264.00
Patent Quality Index	2575	7	26.23	6.46	4.29	26.27	68.45
Patent Quantity (log)	1097	61	3.63	1.04	0.36	3.61	6.63
Market Finance (log)	1742	37	3.76	1.06	0.02	3.79	7.48
Bank Finance (log)	1746	37	4.22	0.67	2.06	4.28	5.72
Venture Capital (log)	637	77	1.52	0.98	0.00	1.38	6.17
IPR Strength (Centered)	157	30	-0.00	1.05	-3.24	0.30	1.56
GDP per Capita (log)	2440	12	9.86	0.96	5.98	10.03	12.03
Trade Openness (log)	2350	16	4.32	0.65	2.31	4.26	6.09
R&D Expenditure (log)	1332	52	0.82	0.40	0.04	0.78	1.95
Tertiary Enrollment (log)	1343	52	3.92	0.62	0.94	4.11	5.12

Table A.2: Venture Capital and Patent Quality

	Dependent Variable: Patent Quality (0–100)				
	quality_index_100				
	(1)	(2)	(3)	(4)	(5)
ln_vc	−0.517	−0.388	−0.354	−0.404	−0.259
	(0.550)	(0.529)	(0.522)	(0.608)	(0.712)
ipr_c	−0.029	0.222	0.286	0.354	0.688
	(1.041)	(0.988)	(1.032)	(1.189)	(0.980)
ln_vc_x_ipr	0.071	−0.087	−0.119	−0.088	−0.059
	(0.701)	(0.723)	(0.754)	(0.849)	(0.828)
ln_gdp_pc		−1.810	−1.844	−1.986	−3.793
		(2.292)	(2.269)	(2.222)	(2.862)
ln_trade			0.401	−0.118	0.953
			(1.975)	(2.050)	(2.306)
ln_rd				1.191	0.718
				(1.702)	(2.089)
ln_tertiary					−3.656
					(2.236)
Observations	428	428	428	408	358
R^2	0.005	0.008	0.008	0.009	0.024
Adjusted R^2	−0.121	−0.121	−0.124	−0.133	−0.142
Note:	*p<0.1; **p<0.05; ***p<0.01				
	Country and year fixed effects included in all models.				
	Standard errors clustered by country.				

Table A.3: Bank Finance and Patent Quantity

	Dependent Variable: ln(Patents per 1,000 Researchers)				
	ln_patents				
	(1)	(2)	(3)	(4)	(5)
ln_bank	0.085	0.021	0.022	−0.004	0.186
	(0.142)	(0.166)	(0.166)	(0.161)	(0.210)
ipr_c	−0.611	−0.426	−0.468	−0.629	−1.427*
	(0.921)	(0.661)	(0.635)	(0.652)	(0.801)
ln_bank_x_ipr	0.286	0.156	0.166	0.206	0.379**
	(0.287)	(0.165)	(0.158)	(0.158)	(0.186)
ln_gdp_pc		1.276**	1.289**	1.379**	1.147**
		(0.620)	(0.619)	(0.624)	(0.503)
ln_trade			0.108	0.149	0.208
			(0.286)	(0.283)	(0.291)
ln_rd				−0.462	−0.631
				(0.552)	(0.442)
ln_tertiary					0.514*
					(0.269)
Observations	813	801	801	800	614
R^2	0.125	0.219	0.220	0.228	0.370
Adjusted R^2	0.036	0.138	0.138	0.146	0.279

Note: *p<0.1; **p<0.05; ***p<0.01
Country and year fixed effects included in all models.
Standard errors clustered by country.

Table A.4: Venture Capital and Patent Quantity

	Dependent Variable: ln(Patents per 1,000 Researchers)				
	ln_patents				
	(1)	(2)	(3)	(4)	(5)
ln_vc	-0.215^{**}	-0.222^{**}	-0.193^{**}	-0.126	-0.002
	(0.102)	(0.091)	(0.089)	(0.084)	(0.073)
ipr_c	-0.338	-0.359^{*}	-0.322	-0.343^{*}	-0.218
	(0.250)	(0.214)	(0.204)	(0.183)	(0.156)
ln_vc_x_ipr	0.155	0.163	0.136	0.072	-0.015
	(0.111)	(0.111)	(0.117)	(0.123)	(0.111)
ln_gdp_pc		0.142	0.118	0.459^{*}	0.775^{***}
		(0.401)	(0.401)	(0.278)	(0.230)
ln_trade			0.351	0.502	0.220
			(0.415)	(0.408)	(0.326)
ln_rd				-0.962^{*}	-0.719^{*}
				(0.498)	(0.389)
ln_tertiary					0.225
					(0.270)
Observations	375	375	375	375	329
R^2	0.039	0.040	0.051	0.122	0.082
Adjusted R^2	-0.099	-0.101	-0.093	-0.014	-0.083

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$
Country and year fixed effects included in all models.
Standard errors clustered by country.

Table A.5: ZINB: Bank Development and Breakthroughs

Intensity: Negative Binomial Count	Model 1	Model 2	Model 3	Model 4
Intercept (Count)	-9.453***	-9.553***	-9.948***	-8.927***
	(0.761)	(0.721)	(0.689)	(0.973)
IPR Strength	-0.509***	-0.491***	-0.636***	-0.597***
	(0.071)	(0.070)	(0.136)	(0.161)
Bank Credit	0.207**	0.156	-0.030	-0.205
	(0.097)	(0.098)	(0.190)	(0.217)
Bank Credit × IPR	0.143	-0.023	0.456**	0.686***
	(0.096)	(0.102)	(0.193)	(0.226)
GDP per Capita	0.373***	0.528***	0.355***	0.069
	(0.074)	(0.075)	(0.084)	(0.105)
Trade Openness		-0.352***	-0.044	0.254**
		(0.056)	(0.084)	(0.112)
R&D Expenditure			0.722***	0.961***
			(0.155)	(0.173)
Tertiary Education				0.059
				(0.158)
Log Theta	0.590***	0.716***	0.769***	0.795***
	(0.089)	(0.094)	(0.106)	(0.121)
Selection: Logit Structural Zero	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Intercept (Zero)	11.465***	10.419	832.493	17.435
	(4.165)	(6.481)	(1195.555)	(10.774)
GDP per Capita (Selection)	-1.629***	-1.587*	-124.179	-2.464
	(0.554)	(0.898)	(178.258)	(1.526)
Num.Obs.	1337	1331	929	728

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Standard errors in parentheses.

Log Theta represents the natural logarithm of the negative binomial dispersion parameter, estimated directly.

Table A.6: ZINB: Venture Capital and Breakthroughs

Intensity: Negative Binomial Count	Model 1	Model 2	Model 3	Model 4
Intercept (Count)	-8.201***	-8.403***	-10.171***	-8.844***
	(1.618)	(1.631)	(1.986)	(2.939)
IPR Strength	-0.887***	-0.932***	-0.901***	-0.636**
	(0.192)	(0.198)	(0.228)	(0.256)
Venture Capital	-0.049	-0.042	-0.154	-0.024
	(0.145)	(0.145)	(0.164)	(0.178)
Venture Capital × IPR	0.434***	0.405***	0.469***	0.358*
	(0.146)	(0.150)	(0.162)	(0.186)
GDP per Capita	0.283*	0.342**	0.428**	0.202
	(0.148)	(0.162)	(0.190)	(0.233)
Trade Openness		-0.087	-0.040	0.083
		(0.100)	(0.106)	(0.128)
R&D Expenditure			0.507**	0.483*
			(0.230)	(0.253)
Tertiary Education				0.056
				(0.262)
Log Theta	1.015***	1.021***	1.015***	0.994***
	(0.136)	(0.137)	(0.139)	(0.146)
Selection: Logit Structural Zero	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Intercept (Zero)	39.580***	38.812***	36.476***	52.394***
	(9.254)	(9.304)	(11.430)	(18.440)
GDP per Capita (Selection)	-4.166***	-4.093***	-3.914***	-5.502***
	(0.940)	(0.944)	(1.160)	(1.936)
Num.Obs.	428	428	408	358

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Standard errors in parentheses.

Log Theta represents the natural logarithm of the negative binomial dispersion parameter, estimated directly.

A.3 Supplementary Figures

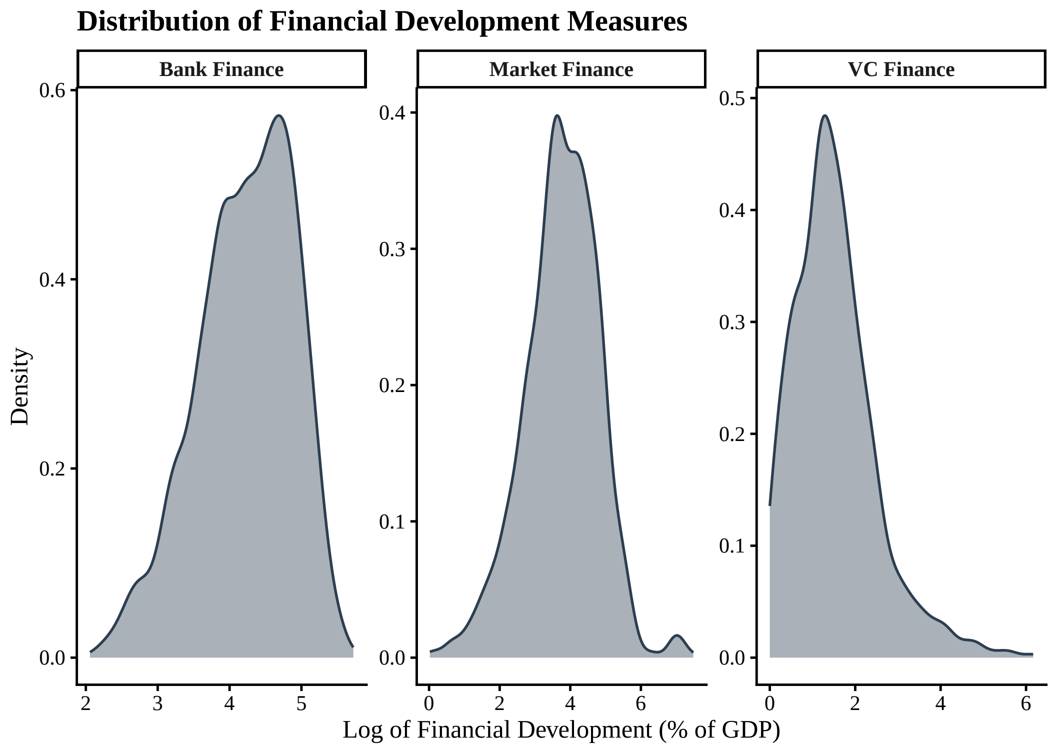

Figure A.1: Financial Development Distributions

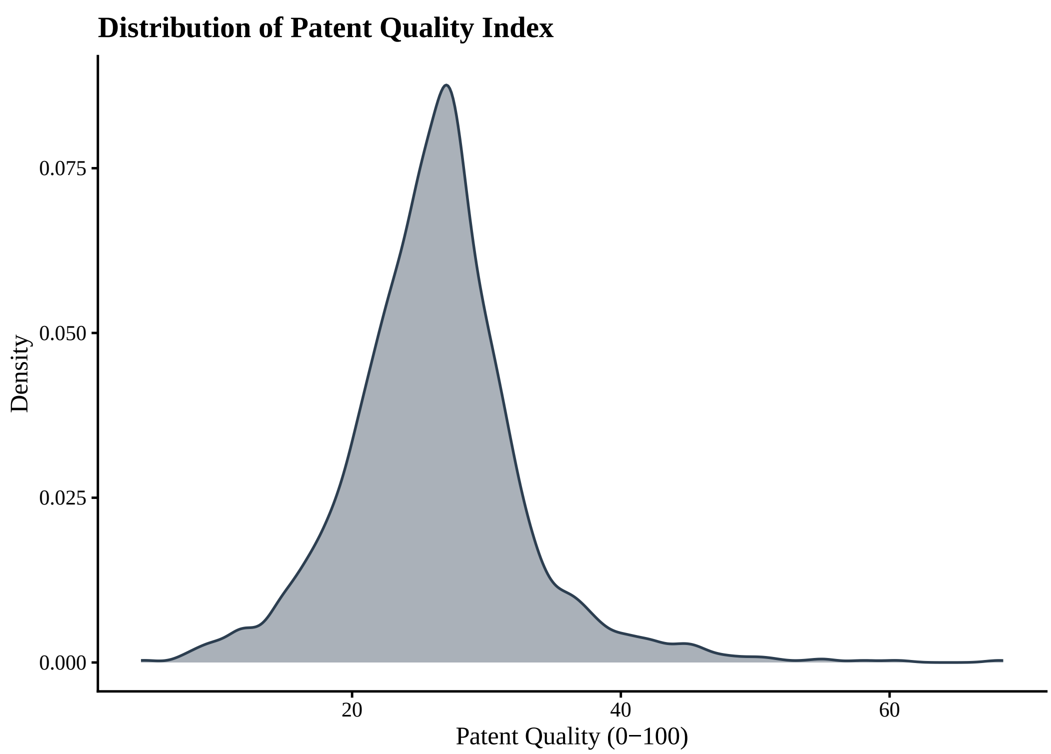

Figure A.2: Patent Quality Density by Variable

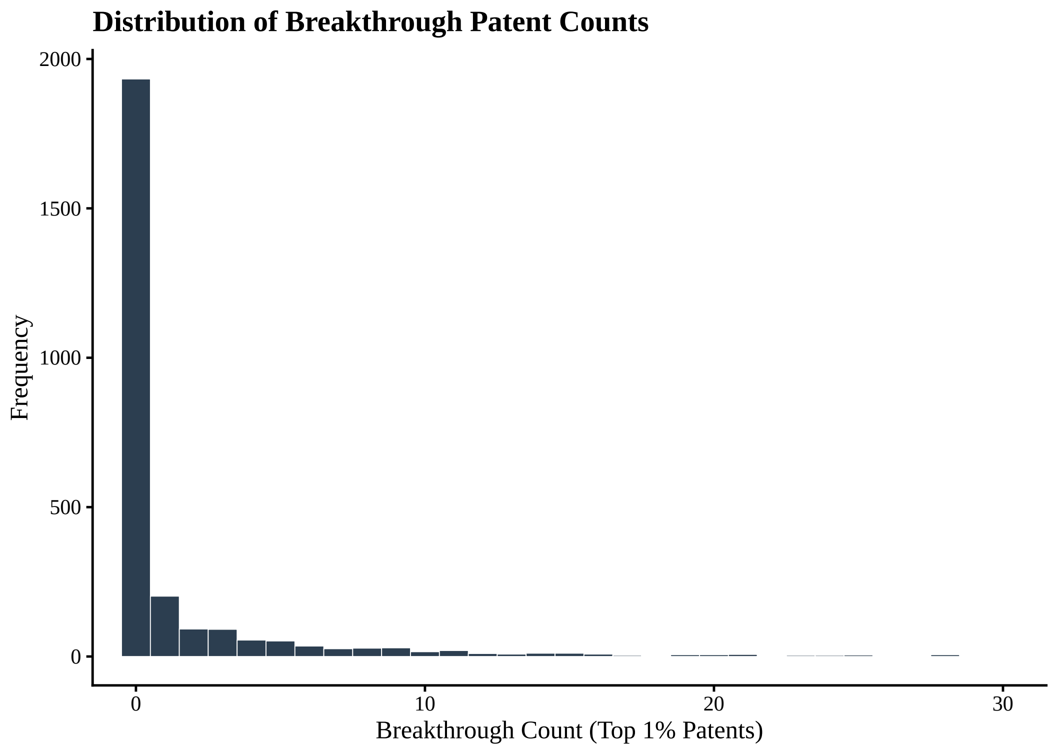

Figure A.3: Breakthrough Patent Distribution

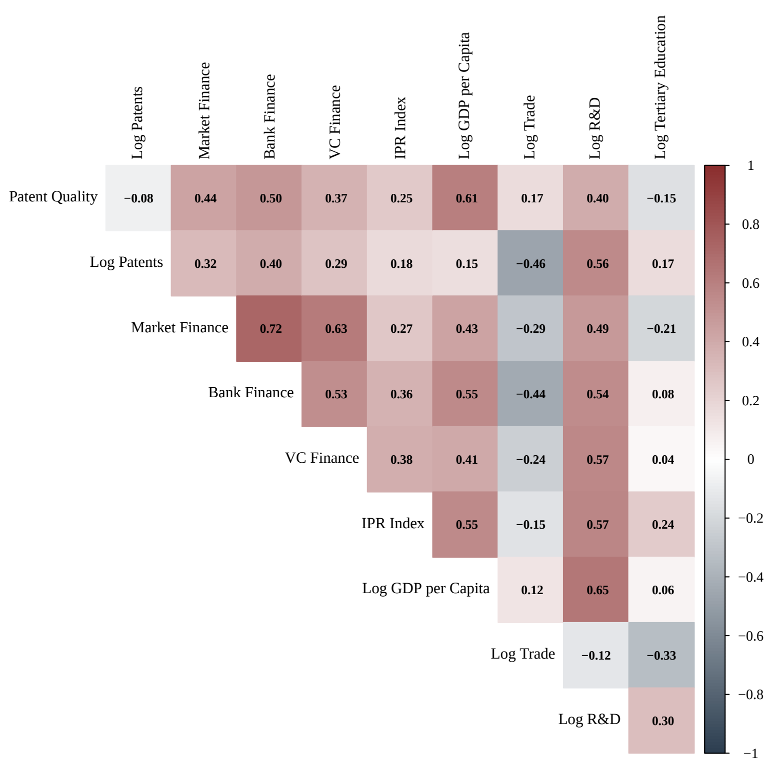

Figure A.4: Correlation Matrix of Key Variables

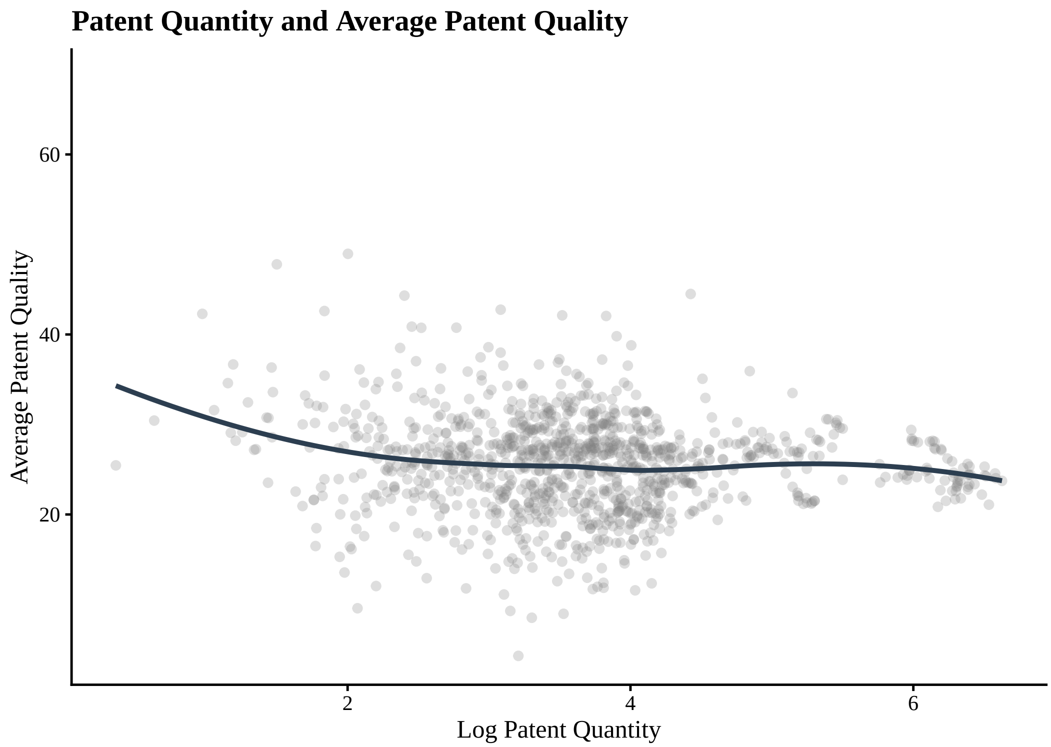

Figure A.5: Patent Quality vs. Patent Quantity

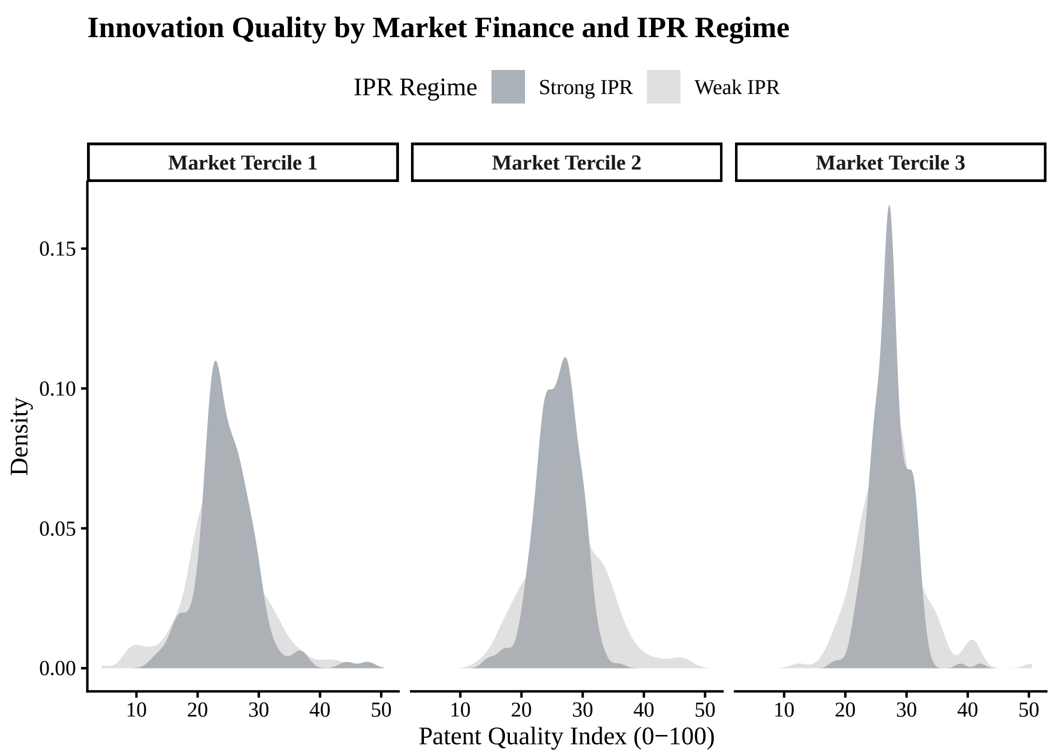

Figure A.6: Innovation Quality by Financial Regime

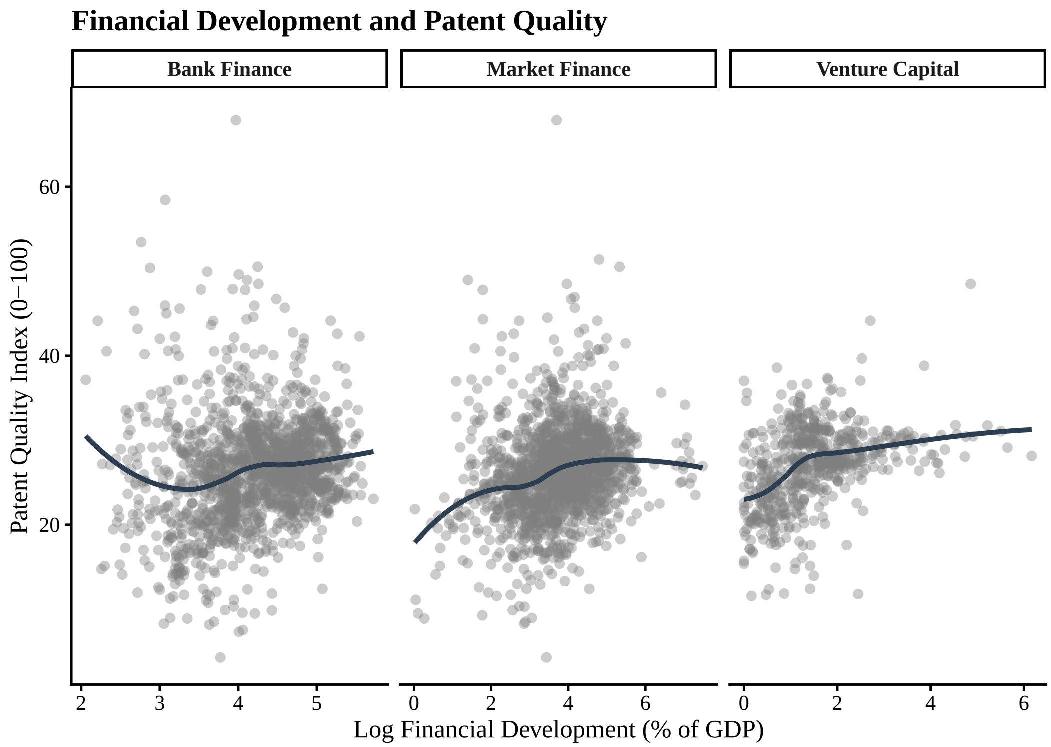

Figure A.7: Scatter: Financial Development and Quality

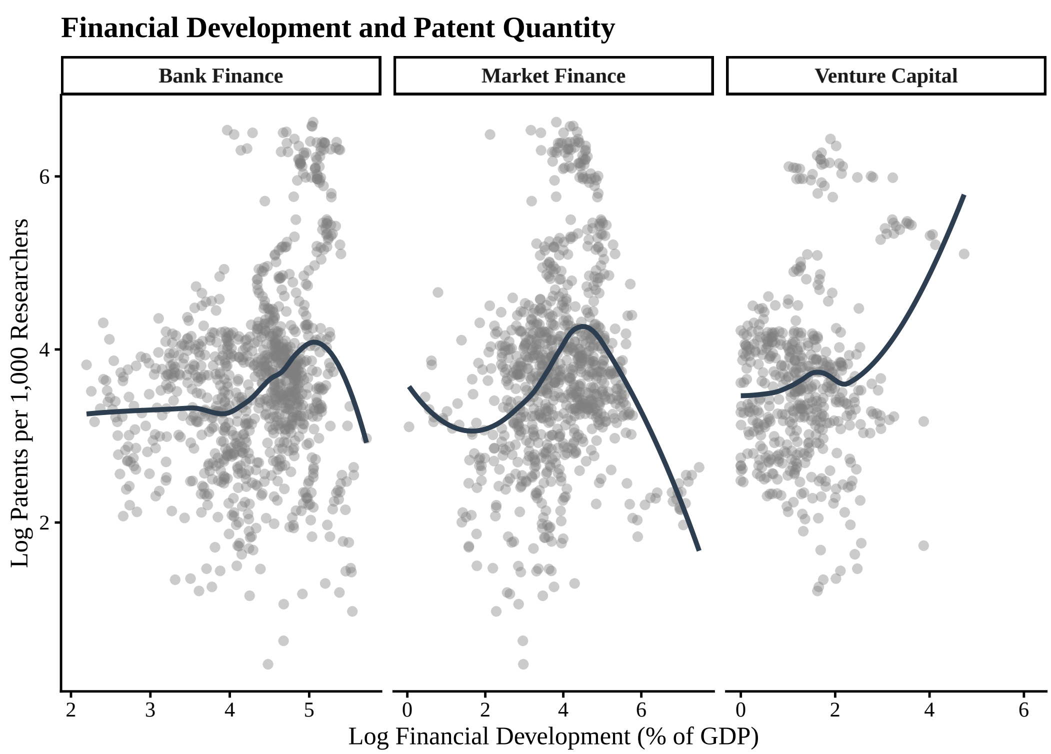

Figure A.8: Scatter: Financial Development and Quantity

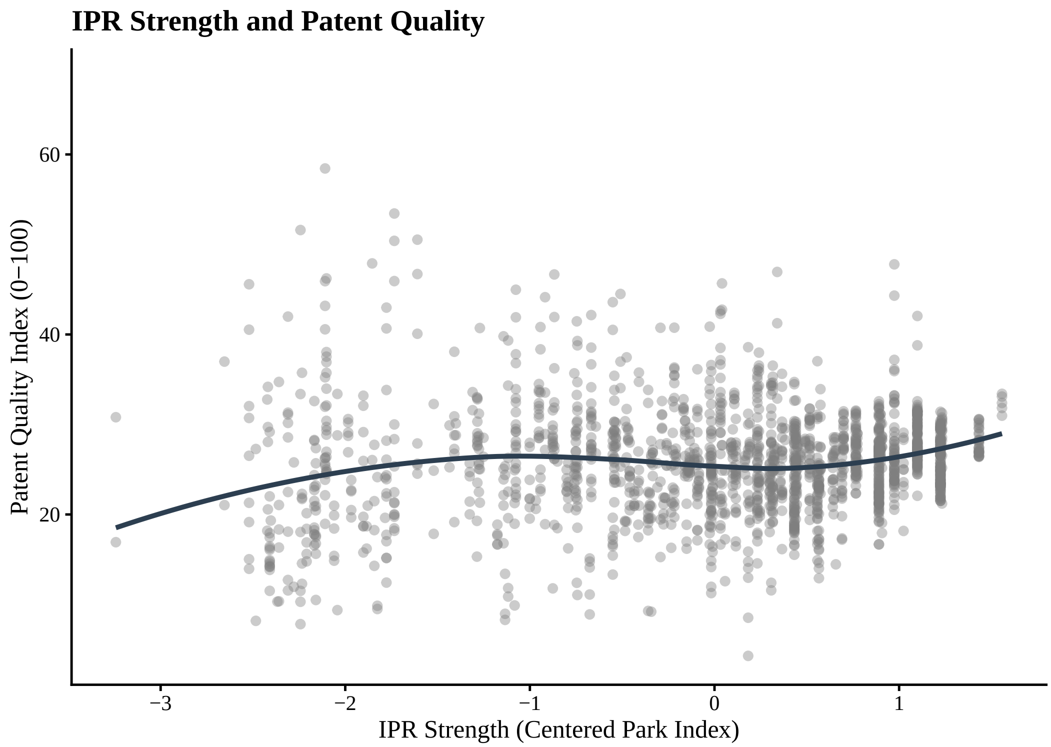

Figure A.9: Scatter: IPR Strength and Quality

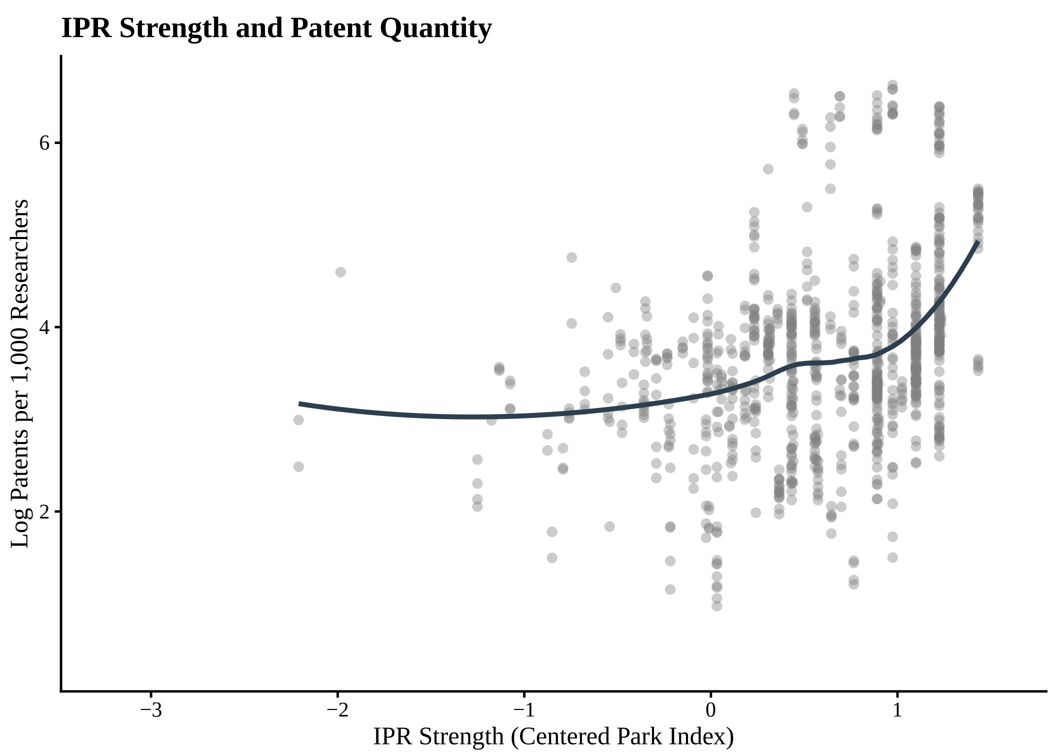

Figure A.10: Scatter: IPR Strength and Quantity

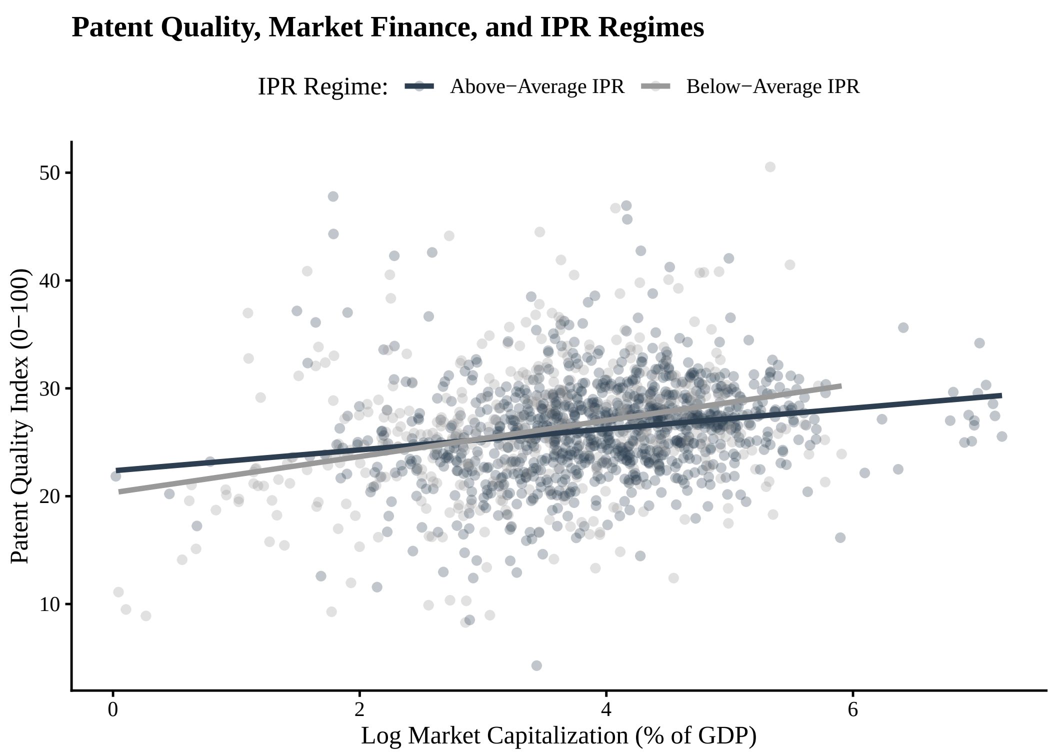

Figure A.11: Binned Interaction Scatterplot

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„Die Lust der Zerstörung ist zugleich eine schaffende Lust."

Mikhail Bakunin

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