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Financial Innovation and Fragility*

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Abstract

In this paper, I evaluate the impact of innovative activity of financial agents on their fragility in a competitive framework. There exist a vast array of concerns about the interconnection of financial innovations, financial distress of firms and financial crises provided by theoretical arguments. I build on these and assess empirically the causal link between a financial agents' innovativeness and stability.

Using a unique data set on financial innovations in the USA between 1990 and 2002, I show that a larger degree of innovation negatively (positively) affects firm stability (fragility) after controlling for the underlying firm characteristics. The results are robust against different modifications of innovation measures and against different fragility parameters indicating profitability, activity risk and risk of insolvency.

JEL Codes: G01, G2, L11, O31

Keywords: Incentives to Innovate, Financial Innovation, Fragility

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1 Introduction

Numerous researchers have analyzed the causes for distress of financial agents during the recent financial crisis starting in 2007. Through both theoretical and empirical analyses, they came up with a variety of reasons. These include panics of bank customers and major investors, shocks to money supply, debt financing and to the real economy, as well as the interconnectedness of banks and their complexity. A recent strand of literature[1] tries to argue, however, that a competitive financial system and the non-patentability of financial innovations (FI) can cause a financial crisis. These papers analyze the incentives to innovate and the relation to financial distress. Despite the plentiful theoretical literature, only a few empirical studies on that relation exist. These have provided evidence on the drivers for product development and competition in financial markets. This work provides additional insight into the empirical relationship between innovation and stability in financial markets.

In this paper, I follow the *innovation-fragility view*[2] and explore whether more innovative financial systems are more prone to financial crises. To do so, I analyze the proposed causal and positive relationship between FI and incidents of a financial distress in an empirical setup with US data on the agent level. The precipitating question is who innovates in the financial market? Is the degree of innovativeness positively related to an agent's profit volatility? Does innovative activity increase the risk of insolvency? In other words, is competition through innovation negatively related to stability?

[1] Starting with Bhattacharyya/Nanda (2000). A more detailed literature review is given in Section 2. This also provides the theoretical underpinnings for the empirical analyses in Section 3.

[2] See Beck et al. (2012).

I utilize count data and patents to measure FI on a micro level from Lerner (2006) and relate agent-level variations in innovativeness to profit volatility of financial institutions while controlling for firm characteristics and time trends. Based on an empiral setup that corresponds to Hasan et al. (2009), Demirgüç-Kunt and Huizinga (2010), Beck et al. (2012), and Lepetit and Strobel (2012), I investigate the link between profit volatility and FI in a dynamic panel model. I find a significant positive relation which implies a negative impact on the stability of the financial system. Furthermore, I check my results against a number of different extensions. While regressions with interactions between firm characteristics and FI provide ambiguous results, my findings are confirmed with different innovation measures and different fragility measures. In addition, more innovative firms face higher losses during a period of crisis.

The paper is structured as follows. First, I discuss previous literature in the area. In Section 3 I introduce the data while in Section 4 I present the empirical analysis. In Section 5 I discuss the results, while Section 6 concludes the paper and suggests topics for future research.

2 Literature Review

This paper draws on literature from two distinct research areas: (i) micro- and macroeconomic research on the existence of financial crises and (ii) investigations into the foundations of FI.[3]

2.1 Financial Crises

The first field of research pertains to the origins and persistence of financial crises, or more particularly, the investigation of causes for financial distress of single agents providing any kind of financial services. In their seminal paper, Allen and Gale (2000) investigate possible contagion and bubbles in financial networks. They build a model of contagion with perfectly competitive banking and show that a first-best allocation of risk-sharing is possible, but fragility still persists. Subsequently, Upper and Worms (2004) confirm Allen and Gale's (2000) model by empirically evaluating the risk of contagion and credit risk in the German interbank lending market.[4] Their analysis provides two results: First, credit risk may trigger a domino effect in that there exists considerable scope for contagion even with safety mechanisms. Second, more concentrated structures can lower the threshold for contagion.[5]

Furthermore, Allen and Gale (2004) analyze the relation between competition and financial stability. Here, they find a negative trade-off between both while considering a variety of different settings such as general equi-

[3] General surveys about research on financial agents with particular focus on asymmetries of information and security design are given by Allen and Winton (1995) and Duffie and Rahie (1995).

[4] They use balance sheet data of German banks to estimate bilateral credit relationships.

[5] Many more papers can be found which empirically analyze the causes for financial crises both at a micro- and macro-level. Since I want to focus on the distinct relationship between FI and financial health, an extended overview on that area of literature would be beyond the scope of this paper.

librium models, agency models, Schumpeterian competition and contagion. In a three-period model with risky and standard assets as well as timing incongruity, they show that greater competition is good for efficiency, but bad for financial stability. Additionally, Allen et al. (2009) provide a thorough review on financial crises. They find that most financial crises arise from panics, business cycle fluctuations or contagion, and derive from this evidence a common sequence of events.[6]

2.2 Financial Innovations

A second strand of literature looks at the origins and existence of financial innovations.[7] The seminal definition of FI is given by Tufano (2003): It is the creation of financial instruments (both product and process) by invention or diffusion of products, services or ideas. He states that FI exists because of the incompleteness of markets, for managing risk, for pooling of funds and because of regulation. Frank and White (2004, 2009) review the technological changes and innovations in commercial banking over the last 25 years. They employ the same definition of FI as Tufano (2003) and argue that FI reduce costs and risks, pool funds and provide a tool to serve demands of investors. In addition, they survey the literature to illustrate innovation patterns over the investigated period.

From a theoretical perspective, numerous papers provide arguments for the existence of innovations in financial markets. Most recently, Michalopoulos

[6] With surging money supply, asset prices and credit volumes increase which inevitably lead to a price bubble bound to burst. A banking crisis is then followed by an exchange-rate crisis and a substantial drop in real output. Brunnermeier (2009) presents an overview on the development of the recent financial crisis and uses micro- and macro-level data to suggest reasonable policy interventions.

[7] Tufano (2003), Frank and White (2004, 2009) as well as Lerner and Tufano (2011) provide overviews on innovations in the financial market.

et al. (2011) link FI to the endogeneous growth theory while Carvajal et al. (2012) examine innovations in frictionless financial markets with short selling. They find incomplete markets even with costless innovation and competition. Ferreira et al. (2012) argue that the form of equity financing determines FI incentives. In their model, they suggest to go public for exploiting existing ideas and go private for exploring new, risky ideas. Song and Thakor (2010) and Shen et al. (2012) provide arguments for collateral-motivated FI and link possible innovation cycles in financial markets to government regulation such as *Basel III*.

Empirical assessments of innovations in financial markets have started with research in the 1980s and 1990s.[8] In his early contribution, Tufano (1989) argues that FI provide first-mover advantages. He assesses the dynamics of innovations and competition by analyzing data on 58 publicly offered FI in the years 1974 to 1987 which raised USD 280 billion and providing cross-sectional regressions of the underwriting spread on firm characteristics.[9] He finds that 20% of new securities being issued in 1987 have not been in existence in 1974 and that new product ideas diffuse rapidly across competitors so that banks do not enjoy monopoly pricing with innovations, but rather capture a larger market share with lower prices than their imitators.

Lerner (2002) looks at financial patents during the period 1971 to 2000 and analyzes the impact of the *State Street* decision[10] on the degree of inno-

[8] See e.g. Miller (1986, 1992), Merton (1992), Frank and White (2004, 2009).

[9] Tufano (1989) relied on three data sources: first, a literature search using ABI-Inform and Business Periodical Index; second, interviews with investment bankers; third, company data from SDC and IDDIS.

[10] *State Street Bank vs. Signature Financial Group* was a 1998 decision by the US Court of Appeals for the Federal Circuit (CAFC) regarding the patentability of business methods. Herein, the CAFC rejected the notion of a *business method exception* and allowed the protection of an invention if it involved some practical application and some tangible

vation observable in the market. He uses the classification of the US Patent and Trademark Office and the Delphion IP Network to identify 445 financial patents and finds a surge in patenting filed mostly by large corporations. In addition, Lerner (2006) investigates the origins of innovations by developing a new measure for FI. His regressions show that small, less profitable firms are more innovative with an additional agglomeration effect. More recently, Lerner (2010) inquires about litigation of patents on FI.[11] He analyzes financial patent awards by the US Patent and Trademark Office between 1976 and 2003 in combination with firm-level data from public records. He finds that first, patents on FI are litigated more often than normal patents; second, litigated patents are mostly owned by small firms or individuals and have more claims and citations than other financial patents; and third, large firms are more often defendants in litigation.

Finally, Boz and Mendoza (2010) examine the interaction of FI, learning and collateral constraints in a stochastic equilibrium model of household debt and land prices. They use an experimental setup with switching between high- and low-leverage regimes according to Bayesian learning and find that innovations in financial markets lead to boom-bust cycles.

The financial innovations considered in this paper differ from innovations in product markets in several important ways. In general, consumers of financial services face opacity about the portfolio of financial agents and their quality provided in financial services. Also, research has not yet produced

result, which with regards to financial patents was deemed the pricing. However, the 2008 CAFC decision *In re Bilski* rejected the tangible result test as inadequate. The US Supreme Court affirmed this judgement in *Bilski vs. Kappos.* This leaves companies with great uncertainty over the patentability of financial innovations.

[11]This again draws on Lerner (2002).

any structural model with which to estimate both supply and demand of FI. Frank and White (2004) survey empirical studies on FI and point to the general scarcity in research in that field. Lerner and Tufano (2011) also show some differences between FI and manufacturing innovations, most notably stressing different dynamics and agency structures. They point out the problems of assessing FI due to the rarity of R&D spending by financial agents, the infrequency or non-existence of financial patents and the opacity of FI by private firms.

2.3 Incentives to Innovate and Financial Crises

This paper makes use of a new strand of literature combining both aforementioned research fields. Most work focuses on the *innovation-fragility view* coined by Beck et al. (2012) that innovations may have adverse effects on competition and stability. It begins with early theoretical work by Bhattacharyya and Nanda (2000). Their paper is the first to connect incentives to innovate and the analysis of financial crises in a theoretical setup. Because client characteristics, market structure and the volatility affect switching costs and costs of delayed adoption, banks with greater market power and more secure relationships with customers are more likely to innovate. Empirical assessments of the causal link between innovations and financial instability have been scarce.

Most recently, two lines of argumentation have emerged. The first one focuses on incentive structures and volatility in financial markets. Thakor (2012) analyzes the relation between incentives to innovate and financial crises. He makes use of Allen and Gale's (2004) model with three periods where the distinction is not between standard and risky assets, but now between standard and innovative assets. Financial agents then face the trade-off between making profits from innovation and refinancing risks. In his model, the degree of innovativeness is positively related to the refinancing risk which makes imitation less likely and drives up profits. Reasons for financial distress are then the competitive financial system and the non-patentability of FI because of the correlation of default risks if FI can be imitated.

Beck et al. (2012) evaluate the respective relationships between FI and real sector growth, real sector volatility and bank fragility using bank-, industry- and country-level data from 32 countries during the period 1996 to 2006. Approximating Tufano's (2003) definition of FI by financial R&D intensity obtained from the OECD, they analyze the *innovation-fragility view* on FI. Namely, they relate country-level variation in FI to bank-level variation in profits and volatility. Their results show that innovativeness leads to increasing fragility, risk taking, profit volatility and bank losses during crises. Herein, smaller, fast growing banks are more fragile in countries with more FI while smaller, less leveraged banks are more effected by agglomeration effects.

A second line of argumentation focuses on investors' behavior. Shleifer and Vishny (2010) set up a behavioral finance model where they assume optimism of investors as stimulus for demand for new securities and pessimism as a shock leading to financial crises. Mispricing occurs because financial agents profit from investors' misperceptions. Depressed securities then have adverse welfare effects ex post as they cut off lending to new instruments. Overall, securitization raises the level of investment and cyclicality. Henderson and Pearson (2011) show that investors can be exploited by innovative financial products. Their event study proposes that issuers innovate to sell new securities at a risk-adjusted premium to uninformed investors because innovativeness increases complexity and ambiguity. Subsequently, issuers exploit investors' misunderstandings of financial market. The authors provide reasons for excess demand in overconfidence, framing and loss aversion of investors.

Jeon and Nishihara (2012) extend Shleifer and Vishny's (2010) model and allow agents to securitize risky assets with leverage and asymmetric information. They find that risk retention requirements imposed by governments reduce welfare. Concurrently, Gennaioli et al. (2012) argue that FI cause crises because of neglected risks. Their research is also an extension of the Shleifer and Vishny (2010) paper whereby agents engineer securities perceived to be safe but exposed to neglected risks which leads to excessive security issuance. They apply a model of belief formation to relate FI, security issuance, risk perception and financial fragility.

This paper follows the recent strand of new literature on the relationship between incentives to innovate and financial instability. The paper's contribution is the empirical connection between financial innovations and instability of financial agents. There exist only a few empirical analyses focusing either on particular innovations (Henderson and Pearson 2011) or on cross-country comparisons (Beck et al. 2012) so far. To the best of my knowledge this paper is the first quantitative assessment of the *innovation-fragility view* at the agent level. I employ a data set by Lerner (2006) and augment it with performance and stability measures so that I can study the effect of firm-level variation in FI on the stability of financial agents. Although I focus here on the USA, this firm-level analysis can offer insights into the incentives to innovate and dynamics in a competitive financial system.

3 Data

The data set measures financial innovations in the USA from 1990 until 2002 via a unique counting mechanism.[12] Lerner (2006) investigates the origins of innovations and develops a new FI measure based on news stories from the Wall Street Journal during the period 1990 to 2002 which he merges with additional information from the SEC, Compustat, finance journals and the US Patent and Trademark Office to establish a link between innovative ability, firm characteristics and patenting.[13] The sample consists of firms with either at least one innovation observed by the measure during the time period or being active in the SIC codes 60 through 64 and 67.[14]

The data set consists of four different groups of variables:[15] First, I use firm characteristics to control for firm-specific effects. In accordance with Lerner (2006), I use the logarithm of total assets to measure firm size. Profitability ($Opprof$) is defined as earnings before interest, taxes, depreciation and amortization ($EBITDA$) divided by revenues, and leverage is defined as the ratio of the book value of a firm's long-term debt to total capitalization. Further control variables include firm age, cash equivalents, employees, shareholders' equity, long-term debt, common market value and revenues.

[12] The data were kindly provided by Josh Lerner, Harvard Business School.

[13] See also Lerner (2002) for his aforementioned earlier work on financial patents.

[14] These SIC codes include firms operating in the financial services business such as insurance, banking, financial advisory and so on except for real estate.

[15] For complete descriptions of the variables used here, see Table A1 in the Appendix.

Second, the data set includes performance measures like EBITDA, net income, retained earnings as well as return on assets (ROA) and return on equity (ROE) which are used to derive the stability measures and provide information about the competitive nature.

Third, I measure stability of financial institutions with the Z-score. The Z-score is a measure of bank solvency and corresponds to $(ROA+CAR)/\sigma(ROA)$. It "indicates the number of standard deviations that a bank's rate of return on assets can fall in a single period before it becomes insolvent. A higher Z-score signals a lower probability of bank insolvency" (Beck et al. 2012).[16] For robustness checks, I later also use other stability measures such as the capital-asset ratio (CAR), standard deviations of returns, and the Sharpe ratio which is defined as $ROE/\sigma(ROE)$.

Fourth, innovation is measured by the count of patent applications, patents issued and stories on innovations per year and firm. I also include a measure for the agglomeration effect by counting the number of innovations by other firms within the same two-digit ZIP code area as a firm.

All financial data is in million 2002 US Dollars. Financial and company data comes directly from Compustat or is calculated from its pool of variables. The count data on innovations comes from articles issued in the Wall Street Journal or the Factiva database on technological inventions. Patent data comes from the US Patent and Trademark Office. For a comprehensive explanation of the data set, see Lerner (2006). I clean the data from coding

[16] See Lepetit and Strobel (2013) for more information on firm's insolvency risk and different approaches to time-varying Z-score measures. They provide a derivation of the Z-score and discuss several ways to estimate means and standard deviations of the variables used to calculate the measure. I follow their recommended specification.

errors and outliers, and perform some plausibility checks. Any observations with implausible values for balance sheet items (e.g. negative revenues) are dropped. I also exclude observations with negative Z-scores. The final sample is an unbalanced panel with 19,895 firm-year observations of 3,042 firms.

Like any other measure of FI, the count measure used here also has its limitations. It necessarily excludes private firms not listed in Compustat. Furthermore, the time period is rather limited and the methodology to source the counts of innovations from the articles is based on stylized facts of FI. Also, problems in assessing FI exist due to the rarity of R&D spending by financial institutions, the infrequency of financial patents and the intransparency of FI by private firms as discussed by Tufano (2003), Frank and White (2004, 2009) and Lerner and Tufano (2011). Therefore, the count measure introduced by Lerner (2006) and applied here to analyze financial fragility is a promising first start to assess empirically the connection between financial innovations and instability of financial agents.

4 Empirical Analysis

This section explores the relationship between FI and financial agents' fragility empirically. I first provide a description of the data and then present the empirical model specification.

4.1 Descriptive Statistics and Properties

Table 1 provides an overview of the summary statistics of the variables. It shows that there exists great heterogeneity among firms in terms of size and profitability. Because I include all firms active in financial services, leverage ratios are comparably low. Stability measures are constructed from the firm characteristics to capture a firm's insolvency risk and activity risk. Higher numbers for the Sharpe ratio and the Z-score reflect less fragility. Moreover, the count data on FI includes a lot of zeros as indicated by the low means.[17] Generally, variances of the variables are quite large. For most variables, mean values are larger than the median because there are a lot of firms in the sample whose observations depict values close to zero for the variables used here.

Observations are evenly distributed over the time period and firm characteristics exhibit a high degree of persistence. About 11% of firms in the sample have observations for the entire time period. About 26% of firms have 8 or more consecutive observations. On average, the data set has 9 observations per firm.

[17] In total, the data set includes only 588 incidences of financial innovation.

Table 1: Summary Statistics of Key Variables

Variable	Mean	Median	Std. Dev.	Min.	Max.
Age	9.550	6.000	11.971	0	77
Assets	12806.760	604.177	57441.090	0	1097190
Cash Equiv.	1348.839	28.258	8608.241	0	316206
Leverage	0.278	0.213	0.263	0	0.999
Long-term Debt	1698.329	36.057	11639.600	0	468570
Market Value	2939.847	138.685	15583.860	0	535947
Pref. Stock	38.948	0.000	223.152	0	5712
Revenues	2607.716	78.583	11729.980	0	186857
Sh. Equity	1306.896	91.860	5115.215	-515.745	153738
Opprof	0.077	0.291	6.850	-587.544	19.483
Ret. Earnings	776.869	24.195	3527.743	-15801	81210
ROA	0.050	0.011	1.723	-16.444	235.667
ROE	0.835	0.104	49.136	-125.869	4787.999
CAR	0.226	0.127	3.231	-441	3.414
HHI	0.014	0.014	0.002	0.011	0.019
σ(ROA)	0.142	0.008	4.875	0	650.898
σ(ROE)	1.557	0.046	45.011	0	2194.872
Sharpe	3.702	2.211	8.642	-103.399	346.778
Z-score	42.926	22.897	194.269	0	12381.450
Innovations	0.016	0.000	0.165	0	6
Patents	0.033	0.000	0.416	0	15
Applications	0.031	0.000	0.432	0	21
R&D	45.594	0.000	436.137	0	9845
FI by Others	2.442	0.000	3.441	0	12

Notes: N=19,895. The list is ordered according to the four different groups of variables mentioned above. See Table A1 in the Appendix for definitions of the variables. All financial data is in million 2002 US Dollars and comes from Compustat. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006).

Figure 1 displays firm characteristics over time. There exists a general increase in the absolute values of these firm-specific variables. Similar to Figure 1, Figure 2 presents the evolution of a firm's performance and stability measures over the time period. There is no clear trend in rising or falling profitability of financial institutions. While retained earnings and the Sharpe ratio increase over time, operational profitability, the capital-asset ratio and returns on assets and equity decline.

Figure 1: Firm Characteristics

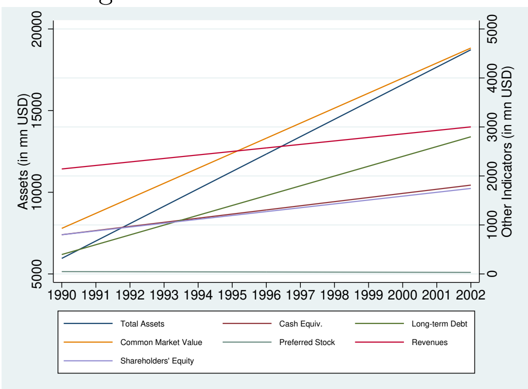


Figure 2: Profitability and Stability Measures

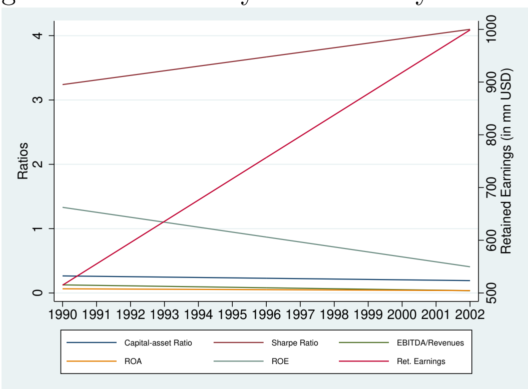


Figure 3 presents how the count of FI has developed over time. The notable peak towards the late 1990s is due to the aforementioned *State Street* decision. Observations for patents lag behind applications because the average time period between applying for a patent and granting patents is about two to three years. Only applications for patents granted during the time period are included in the data set. Overall, the number of observed innovations is rather low in comparison to the overall size of the data set so that this is one point of caution.

Figure 4 presents a comparison of fragility by grouping firms with measured innovation and with no count, respectively, and by plotting the evolution of both sets. In accordance with my hypothesis, linear predictions of Z-scores of firms without innovation are slightly higher than those with counts of innovation. Additionally, a time trend indicates that the relation becomes stronger.

Figure 3: Evolution of Innovative Activity

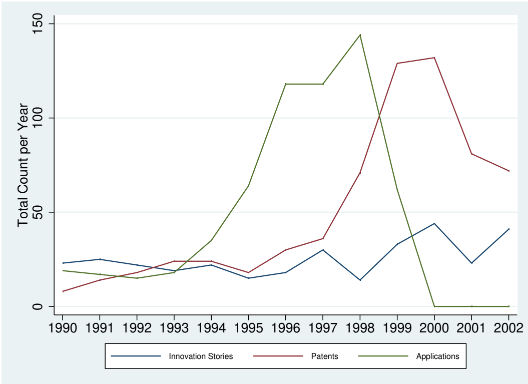
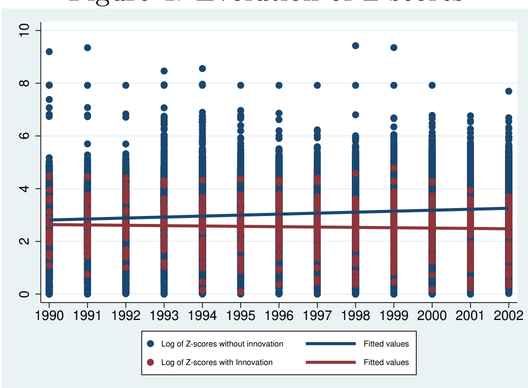


Figure 4: Evolution of Z-scores



Following the descriptives, a variety of univariate analyses provide a first glance at the variables' behavior and properties. Firm characteristics are correlated with each other and over time. This also drives autocorrelation in Z-scores by construction. Including lagged dependent variables in the regressions captures most of the autocorrelation. While the FI measures are significantly correlated with each other, a F-test also shows joint significance. Also, fragility (Z-scores) and FI measures are significantly positively (negatively) correlated.[18] Mann-Whitney U tests show that the mean and variance of Z-scores are significantly different with and without innovation. A series of panel-based unit root tests reject the hypothesis that the Z-scores are first-order integrated ($I(1)$).[19] Control variables are carefully selected to avoid problems of multicollinearity. A robust version of the Wu-Hausman test by Wooldridge (2002) shows that fixed effects modeling is preferred over a random effects setup. Furthermore, Breusch-Pagan and White tests show that error terms are heteroskedastic, while Arellano-Bond and Breusch-Godfrey tests show that the error terms are correlated with each other.

4.2 Empirical Strategy

Based on the micro-level database on FI in the US between 1990 and 2002 presented above, I relate agent-level variations in innovativeness to profitability and profit volatility of financial institutions while controlling for firm characteristics and time trends. For my empirical setup I build on Hasan et al. (2009), Demirgüç-Kunt and Huizinga (2010), Lepetit and Strobel (2012), Beck et al. (2012) and Bertay et al. (2013). They analyze profits and fragility of financial institutions with a variety of different setups and also assess the reliability of the Z-score.[20] Because of the data properties presented above, my baseline model specification is as follows.

[18] See Table A2 in the Appendix.

[19] I use augmented Dickey-Fuller and Phillips-Perron tests to analyze cointegration. If Z-scores were really $I(1)$, then their time series would be a random walk with drift. In fact, the data is trend stationary and I use a time trend in my regression models to account for that.

[20] Their work shows that the Z-score is a feasible indicator to measure financial stability of firms and is commonly used in the literature.

$$Z_{i,t} = \rho Z_{i,t-1} + \beta X_{i,t} + \gamma Y_{i,t} + \alpha_i + \delta_t + \epsilon_{i,t} \tag{1}$$

where indices i, t stand respectively for firm and time, Z is the Z-score per firm and period.[21] Including lagged dependent variables allows me to account for the persistence of firm characteristics which also reflect in the Z-scores by construction and the general persistence over time. X is the vector of firm characteristics for which data are available while Y is the vector of different financial innovation indicators. To account for firm heterogeneity, I use ratios of balance sheet items relative to asset size for the control variables and employ the logarithm of all independent variables that are not ratios. The regression model also includes α_i and δ_t to account for omitted firm-specific and time fixed effects, respectively. The Newey-West-type robust error term ϵ is clustered at firm-level and allowed to be heteroskedastic, autocorrelated and spatially correlated.

[21] Because the Z-score is highly skewed and to avoid truncation, I use $ln(1 + Z\text{-}score)$ in the regressions.

5 Results

In this section, I discuss the main results and perform a number of robustness checks. I also extend the model to further investigate the *innovation-fragility view* in more detail.

5.1 Baseline Model

I compare different versions of the dynamic panel model set up in Section 4.2 which enhances the static linear fixed effects model by including autoregressive coefficients for fragility. This allows me to capture feedback from current or past shocks to current values of the dependent variable. This specification is adequate in the presence of autocorrelated error terms and high persistence in the dependent variable which I have shown earlier.

Table 2 provides the overview of the different model specifications. Baseline innovative capacity in firms is captured by firm size, profitability and leverage which Lerner (2006) has shown to be important drivers of incentives to innovate. In all regressions, I include firm characteristics, year fixed effects and a constant but suppress their coefficients in the tables.

Column 1 to 4 provides the Driscoll-Kraay (1998) estimator with firm fixed effects and lagged dependent variables interchangeably. Column 4 depicts the full model specification presented in Section 4.2. Even though firm fixed effects cover average innovative ability of a firm while lagged dependent variables capture time trends, the γ coefficients to measure FI remain negative and statistically significant. Once accounting for firm differences and time trends, patenting becomes sufficiently less important for firm stability.

Table 2: Variants in the Model Specification

	static ln(1+Z-score$_t$)	**firm FE only** ln(1+Z-score$_t$)	**LDV only** ln(1+Z-score$_t$)	**full specification** ln(1+Z-score$_t$)	**pre-1998** ln(1+Z-score$_t$)	**competition** ln(1+Z-score$_t$)
ln(1+Z-score$_{t-1}$)			0.794***	0.013	-0.005	0.012
			(0.060)	(0.008)	(0.008)	(0.007)
ln(assets)	0.382***	-0.133***	0.111***	-0.139***	-0.166***	-0.138***
	(0.027)	(0.011)	(0.032)	(0.009)	(0.008)	(0.009)
EBITDA/revenues	0.016***	-0.000	0.005***	-0.000	0.000	-0.000
	(0.002)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Leverage ratio	0.144	-0.266***	-0.085*	-0.257***	-0.246***	-0.254***
	(0.162)	(0.026)	(0.051)	(0.020)	(0.025)	(0.020)
HHI						0.162
						(0.435)
FI by others	-0.010	0.003***	-0.003*	0.001*	0.000	0.001*
	(0.008)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Innovations	-0.211***	-0.028**	-0.075*	-0.029**	-0.058*	-0.027**
	(0.034)	(0.012)	(0.042)	(0.012)	(0.031)	(0.012)
Patents	-0.074***	-0.006	-0.016*	-0.004	0.015	-0.004
	(0.012)	(0.006)	(0.009)	(0.005)	(0.009)	(0.005)
Applications	-0.023**	-0.003	0.002	-0.001	-0.003	-0.002
	(0.012)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	Y	N	Y	Y	Y
Constant	Y	Y	Y	Y	Y	Y
Observations	16,717	16,717	14,770	14,770	7,934	14,770
Number of firms	2,715	2,715	2,660	2,660	2,022	2,660
R-squared	0.293	0.594	0.551	0.633	0.629	0.633

Notes: See Table A1 in the Appendix for definitions of the variables. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). All financial data is in million 2002 US Dollars and comes from Compustat. Column 1 does not include a lagged dependent variable or firm fixed effects. Column 2 includes only firm fixed effects. Column 3 includes only a lagged dependent variable. Column 4 includes the full model specification presented in Section 4.2. Column 5 includes data for 1990 until 1998 only. Column 6 includes data for the full period from 1990 until 2002 with the HHI controlling for firm-level competition. In all regressions, I include firm characteristics as controls, year fixed effects and a constant but suppress their coefficients in the tables. Control variables include firm age, cash equivalents, employees, retained earnings, shareholders' equity, preferred stock and long-term debt (all as ratios relative to assets or logarithms). Driscoll-Kraay (1998) robust standard errors are clustered at firm-level and presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Column 5 presents the results for the period 1990 until 1998 only. Remember the *State Street* decision by the CAFC in 1998.[22] This has provided firms with legal certainty about what kind of FI can be legally protected. Hence, more technology spillovers should theoretically be observed in the pre-1998 period because of the legal uncertainty prior to the CAFC decision. Given these spillovers from FI, I expect to observe a stronger relation between firm instability and innovative activity. I split the data sample into pre-*State Street* and post-*State Street* periods. Analyzing the subsample indeed shows larger γ coefficients of the FI measures prior to 1998 and hence confirms that the spillover effect of FI further decreases stability.

Moreover, I analyze the impact of competitive pressure on the proposed positive relationship between FI and fragility. I thus include the Herfindahl-Hirschman Index (HHI) in column 6. Because an increase in the HHI signals rising market power and weakening competition, the positive regression coefficient for the HHI indicates that competition and stability are negatively correlated which is the same conjecture Allen and Gale (2004) made. Controlling for competition does not change the γ coefficients of the FI measures or the agglomeration effect.

Overall, results show that indeed there exists a significant positive relation between FI and fragility (negative relation between FI and Z-scores) albeit small, but patenting seems to be no factor. The size of the coefficients however corresponds to the correlations from the univariate analyses in Section 4.1. Surprisingly, the agglomeration effect as measured in FI by others is very weak.

[22] I already mentioned this in the Literature Review (Section 2) and it is discussed in Lerner (2002).

5.2 Robustness

I check the robustness of my results. Foremost, the results in Table 2 are robust against including or excluding different firm-specific control variables. I also use data on revenues and common market value instead of total assets to control for firm size but the results do not change. If I include a dummy variable for incidences of FI instead of the three different count measures, the coefficient is negative but not significant.

In order to check whether my results are due to a particular econometric specification, I run different panel estimators. I compare my baseline model specification to a pooled feasible GLS estimator with a panel-specific AR(1)-disturbance, a Prais-Winsten regression to account for autocorrelated error terms, and a Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) estimator. I find qualitatively similar results. The advantage of Driscoll-Kraay (1998) standard errors is that they expand Newey-West HAC estimators to include correlation between panels and that the estimator does not place restrictions on the limit behavior of the number of panels.

I also run dynamic panel data estimators. I use the Arellano-Bond (1991) estimator by instrumental-variables (IV) estimation of the parameters of the first-difference model using lags of regressors as instruments.[23] Additionally, I use the Blundell-Bond (1998) estimator because the Arellano-Bond (1991) estimator performs poorly with large autoregressive disturbances.[24] I find

[23] I have shown earlier that the data is trend stationary. Because the Arellano-Bond (1991) estimator relies on first differences, it consumes most of the variation between observations for innovation indicators since their within-variation (variation over time) is larger than their variation between panels. Thus, coefficients for the innovation indicators turn out smaller and not significant in the regression.

[24] The Blundell-Bond (1998) estimator is a system GMM estimation method which enhances the Arellano-Bond (1991) estimator with additional moment conditions. Both

qualitatively similar results.

In any estimation of fixed effects models for short panels when lagged dependent variables are present, coefficients may be downwardly biased. This is called Nickell (1981) Bias whose size is relative to the time period T of the data set. It is given here by $1/T = 1/13 = 0.07$. Thus, as $T \rightarrow \infty$ the bias disappears.[25] That's why I compare the Driscoll-Kraay (1998) estimator with the aforementioned dynamic panel data estimators which are consistent. Two caveats arise from dynamic panel data estimators in this case, namely that the IV estimation greatly increases the mean squared error and that errors are assumed to not be serially correlated. On the other hand, the Driscoll-Kraay (1998) estimator works with great precision although potentially biased. Thus, a trade-off between correcting biases against decreases in efficiency is inherent. Fundamentally, trading a small reduction in the bias for a large decrease in efficiency sounds questionable. Assuming the Nickell (1981) bias is negligible since $T = 13$ is a reasonable time period and given the small coefficient for lagged Z-scores from Table 2, I further pursue the Driscoll-Kraay (1998) estimator with fixed effects and lagged dependent variables in my analysis.

5.3 Extensions

I extend the baseline model with a couple features. First, I want to explore the relationship between innovation and fragility across firms with different characteristics. Thus, I generate interaction terms of the FI measures

estimators are consistent, but they assume that there exists no autocorrelation in the error terms, that panel-level effects are uncorrelated with the first differences and that good instruments are available.

[25] Compare Behr (2003) for a discussion of dynamic panel data estimators and their application to financial data.

with assets, profitability and leverage.[26] Table 3 provides the piece-wise inclusion of these interactions into the regression with the Driscoll-Kraay (1998) estimator assessed above. Column 1 and 4 show the effect of FI on fragility with heterogeneous firm size. The relationship is stronger for larger banks but only for innovative activity captured through patenting. Overall, patenting decreases stability significantly. Column 2 and 4 show that the different profitability levels have no impact on the effect of FI on fragility as expected. Finally, column 3 and 4 display the effect of FI on fragility with different leverage ratios. The relationship is stronger when firms are more leveraged and the impact of innovation increases with the leverage ratio. Across all models, the positive (negative) relation between innovation and fragility (stability) prevails, while the size of the coefficients differs across specifications.

Second, I investigate the robustness of my results from Section 3.4 against modifications of innovation measures as depicted in Table 4. Column 1 provides the regression results with the Driscoll-Kraay (1998) estimator from Table 2. Subsequently, column 2 uses a weighting mechanism to account for sole or collaborative inventions, column 3 uses only highly innovative activities as classified by a three-part scheme introduced by Lerner (2006), column 4 provides a combination of 2 and 3 and finally, column 5 introduces R&D expenditures as a further control.[27] Results are confirmed. The positive relation between innovation and fragility is persistent while patenting has no effect.

[26]For the interaction terms, I multiply my FI indicators with assets, profitability and leverage, respectively.

[27]See Table A1 in the Appendix for a description of the exact modifications.

Table 3: Interaction with Firm Characteristics

	Firm Size	Profitability	Leverage	Compound Model
	ln(1+Z-score$_t$)	**ln(1+Z-score$_t$)**	**ln(1+Z-score$_t$)**	**ln(1+Z-score$_t$)**
ln(1+Z-score$_{t-1}$)	0.013*	0.013*	0.013*	0.013*
	(0.008)	(0.008)	(0.008)	(0.008)
ln(assets)	-0.155***	-0.155***	-0.154***	-0.154***
	(0.013)	(0.013)	(0.013)	(0.013)
EBITDA/revenues	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Leverage ratio	-0.228***	-0.227***	-0.227***	-0.227***
	(0.024)	(0.024)	(0.025)	(0.025)
FI by others in 2-digit zip code	0.002*	0.002*	0.002*	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Innovations	-0.016	-0.010***	-0.103**	-0.097***
	(0.019)	(0.004)	(0.043)	(0.034)
Patents	-0.042***	0.002	-0.036*	-0.035**
	(0.012)	(0.005)	(0.020)	(0.017)
Applications	-0.016	-0.008*	-0.044	-0.060*
	(0.012)	(0.005)	(0.033)	(0.035)
Innovations * ln(assets)	-0.048			0.191
	(0.158)			(0.195)
Patents * ln(assets)	-0.402***			-0.672***
	(0.111)			(0.195)
Applications * ln(assets)	-0.136			-0.029
	(0.091)			(0.081)
Innovations * EBITDA/revenues		0.001		0.001
		(0.001)		(0.001)
Patents * EBITDA/revenues		-0.001***		-0.002***
		(0.000)		(0.000)
Applications * EBITDA/revenues		-0.001		-0.001*
		(0.000)		(0.000)
Innovations * leverage ratio			-0.117**	-0.139**
			(0.052)	(0.054)
Patents * leverage ratio			-0.035	0.027
			(0.022)	(0.020)
Applications * leverage ratio			-0.046	-0.055
			(0.033)	(0.041)
Controls	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Constant	Y	Y	Y	Y
Observations	14,770	14,770	14,770	14,770
Number of firms	2,660	2,660	2,660	2,660
R-squared	0.634	0.634	0.634	0.634

Notes: See Table A1 in the Appendix for definitions of the variables. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). All financial data is in million 2002 US Dollars and comes from Compustat. All columns incorporate the baseline model from column 4 of Table 2. Column 1 includes interaction terms between firm size and FI measures. Column 2 includes interaction terms between profitability and FI measures. Column 3 includes interaction terms between leverage ratio and FI measures. Finally, column 4 includes all interaction terms. In all regressions, I include firm characteristics as controls, firm and year fixed effects, and a constant but suppress their coefficients in the tables. Control variables include firm age, cash equivalents, employees, retained earnings, shareholders' equity, preferred stock and long-term debt (all as ratios relative to assets or logarithms). Driscoll-Kraay (1998) robust standard errors are clustered at firm-level and presented in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Robustness against FI Measures

	base	**weighted**	**major**	**weighted and major**	**R&D**
	ln(1+Z-score$_t$)	**ln(1+Z-score$_t$)**	**ln(1+Z-score$_t$)**	**ln(1+Z-score$_t$)**	**ln(1+Z-score$_t$)**
ln(1+Z-score$_{t-1}$)	0.013	0.013	0.013	0.013	0.013
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
ln(assets)	-0.139***	-0.139***	-0.139***	-0.139***	-0.143***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)
EBITDA/revenues	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage ratio	-0.257***	-0.257***	-0.258***	-0.258***	-0.248***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.018)
FI by others in 2-digit zip code	0.001*	0.001*	0.001*	0.001*	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Innovation parameters	-0.029**	-0.046***	-0.028*	-0.051*	-0.027**
	(0.012)	(0.017)	(0.015)	(0.027)	(0.012)
Patent parameters	-0.004	-0.012	-0.005	-0.014	-0.006
	(0.005)	(0.014)	(0.005)	(0.014)	(0.005)
Application parameters	-0.001	-0.004	-0.001	-0.004	-0.001
	(0.005)	(0.015)	(0.005)	(0.015)	(0.005)
R&D/assets					-0.489***
					(0.144)
Controls	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
Constant	Y	Y	Y	Y	Y
Observations	14,770	14,770	14,770	14,770	14,770
Number of firms	2,660	2,660	2,660	2,660	2,660
R-squared	0.633	0.633	0.633	0.633	0.634

Notes: See Table A1 in the Appendix for definitions of the variables. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). All financial data is in million 2002 US Dollars and comes from Compustat. Column 1 incorporates the baseline model from column 4 of Table 2. Column 2 includes a weighting mechanism to account for sole or collaborative inventions. Column 3 includes only highly innovative activities as classified by a three-part scheme introduced by Lerner (2006). Column 4 is a combination of 2 and 3. It includes a weighting mechanism to account for sole or collaborative inventions of only highly innovative activities as classified by Lerner (2006). Finally, column 5 includes R&D expenditures as a further control. In all regressions, I include firm characteristics as controls, firm and year fixed effects, and a constant but suppress their coefficients in the tables. Control variables include firm age, cash equivalents, employees, retained earnings, shareholders' equity, preferred stock and long-term debt (all as ratios relative to assets or logarithms). Driscoll-Kraay (1998) robust standard errors are clustered at firm-level and presented in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Third, I further explore the robustness of results by investigating the components of the Z-score and alternative measures for firm fragility in Table 5.[28] Thus, I keep the right-hand side variables the same and compare different left-hand side variables. I respectively use ROA, ROE and the capital-asset ratio to assess profitability and capitalization, the volatility of ROA and volatility of ROE to measure a firm's activity risk, and finally, the Sharpe ratio as an alternative measure for the risk of insolvency. Specifically, the Sharpe ratio describes how well the return compensates the investor for the risk taken. Column 2 and 3 show that profitability is positively affected by patenting behavior, but surprisingly, the innovation coefficient is significantly negative although small. Capitalization in column 4 negatively affects firm stability on a small scale, but only in patenting. Unusually, activity risk is not affected by a firm's degree of innovation as depicted in columns 5 and 6. Lastly, innovation continues to positively relate to risk of insolvency although the coefficient becomes insignificant whereas unexpectedly patenting positively affects excessive returns as shown in column 7.

Fourth, another investigation looks at the impact of FI on profitability during a financial crisis. Did FI hurt financial institutions during a period of financial market breakdown? In a cross-sectional setting where independent variables from 1999 only are used, I analyze whether firms make larger losses during financial distress when innovating. Table 6 provides an overview of the summary statistics of the variables for 1999. The cross-sectional sample has 1,781 observations. For most variables, mean values are larger than the median indicating a few large firms drive up average values. Values for most differences in profitability are negative. Variances in general are large.

[28] Because the different measures are highly skewed and to avoid truncation, I use the logarithm for the dependent variables in the regressions, except for standard deviations.

Table 5: Robustness against Fragility Measures

	(1) **ln(1+Z-score$_t$)**	(2) **ln(1+ROA$_t$)**	(3) **ln(1+ROE$_t$)**	(4) **ln(1+CAR$_t$)**	(5) **σ(ROA)**	(6) **σ(ROE)**	(7) **ln(1+Sharpe$_t$)**
ln(1+Z-score$_{t-1}$)	0.013						
	(0.008)						
ln(1+ROA$_{t-1}$)		0.042					
		(0.022)					
ln(1+ROE$_{t-1}$)			0.024				
			(0.015)				
ln(1+CAR$_{t-1}$)				0.327***			
				(0.004)			
ln(1+Sharpe$_{t-1}$)							0.033***
							(0.009)
ln(assets)	-0.143***	0.004	-0.152***	-0.048***	-0.020	-0.083	-0.297***
	(0.008)	(0.007)	(0.022)	(0.005)	(0.017)	(0.066)	(0.024)
EBITDA/revenues	0.000	0.000***	0.001***	0.000	0.000	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Leverage ratio	-0.248***	0.005	0.091***	0.100***	-0.011	-0.158	0.166***
	(0.018)	(0.013)	(0.015)	(0.006)	(0.014)	(0.132)	(0.055)
FI by others in 2-digit zip code	0.001*	0.001	0.003	0.001	0.009	0.002	0.000
	(0.000)	(0.001)	(0.002)	(0.001)	(0.007)	(0.001)	(0.003)
Innovations	-0.027**	-0.003**	-0.004	-0.002	-0.001	-0.037	-0.026
	(0.012)	(0.001)	(0.006)	(0.003)	(0.004)	(0.042)	(0.027)
Patents	-0.006	0.003	0.009**	-0.003***	-0.002	0.001	0.018**
	(0.005)	(0.002)	(0.004)	(0.001)	(0.002)	(0.003)	(0.009)
Applications	-0.001	0.003**	0.007**	-0.002**	-0.002	0.002	0.018***
	(0.005)	(0.001)	(0.003)	(0.001)	(0.002)	(0.002)	(0.006)
R&D/assets	-0.489***	-0.449	-0.498***	0.073	0.159	0.002	-0.253**
	(0.144)	(0.504)	(0.136)	(0.055)	(0.152)	(0.085)	(0.124)
Controls	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y
Constant	Y	Y	Y	Y	Y	Y	Y
Observations	14,770	14,770	14,754	14,824	14,770	14,505	13,960
Number of firms	2,660	2,660	2,658	2,714	2,660	2,659	2,630
R-squared	0.634	0.103	0.071	0.519	0.004	0.002	0.082

Notes: See Table A1 in the Appendix for definitions of the variables. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). All financial data is in million 2002 US Dollars and comes from Compustat. Lagged dependent variables are included in the regressions except for standard deviations of returns. I keep all other independent variables the same and only change the dependent variables from column to column. Column 1 incorporates the baseline model from column 4 of Table 2. Column 2 and 3 measure the impact of FI on profitability where returns on assets and equity are the dependent variables, respectively. Column 4 measures the impact of FI on capitalization of forms. Here, the capital-asset ratio is the dependent variable. Column 5 and 6 measure the impact of FI on activity risk by including the standard deviations of the returns on assets and equity, respectively. For these two regressions coefficients are scaled by 1,000. Finally, column 7 includes the Sharpe Ratio as dependent variable as another stability measure. In all regressions, I include firm characteristics as controls, firm and year fixed effects, and a constant but suppress their coefficients in the tables. Control variables include firm age, cash equivalents, employees, retained earnings, shareholders' equity, preferred stock and long-term debt (all as ratios relative to assets or logarithms). Driscoll-Kraay (1998) robust standard errors are clustered at firm-level and presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Summary Statistics of Cross-Section (1999)

Variable	Mean	Median	Std. Dev.	Min.	Max.
Age	9.226	5.000	11.699	0	74
Assets	15381.500	614.032	65763.220	0	893649
Cash Equiv.	1503.317	27.252	9642.401	0	205371
Leverage	0.326	0.293	0.276	0	0.997
Long-term Debt	1954.220	51.799	12102.890	0	339221
Market Value	4597.746	116.612	26350.170	0.062	535947
Pref. Stock	33.535	0.000	183.772	0	3375
Revenues	2802.985	79.385	12301.180	0	184589
Sh. Equity	1496.865	87.944	5640.443	-44	83397
Δ(Opprof)	-0.533	0.014	16.200	-523.908	130.719
Δ(ROA)	-0.096	-0.001	1.382	-41.827	1.671
Δ(ROE)	0.195	-0.004	6.999	-51.006	230.774
Innovations (avg.)	0.012	0.000	0.075	0	1.200
Patents (avg.)	0.024	0.000	0.219	0	5.000
Applications (avg.)	0.040	0.000	0.352	0	7.000
R&D	48.874	0.000	457.900	0	7502.168
FI by others	1.002	0.000	1.713	0	4.000

Notes: N=1,781. See Table A1 in the Appendix for definitions of the variables. All financial data is in million 2002 US Dollars and comes from Compustat. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). FI measures are averaged over the period 1990 to 1999.

For the cross-sectional analysis, I use as the dependent variable $\Delta(Opprof)$, $\Delta(ROA)$ and $\Delta(ROE)$, respectively, where $\Delta(\cdot) = (\cdot)_{2002} - (\cdot)_{1999}$.[29] I expect that the difference will be negative for most firms and should be larger for more innovative firms. The model specification for the three regressions is as follows.

$$\Delta(\cdot)_i = \beta X_i + \gamma Y_i + \epsilon_i \tag{2}$$

where index i stands for the firm and the dependent variable is the performance change between 2002 and 1999 calculated as the difference in ROA, ROE, $Opprof = EBITDA/revenues$, respectively, between the values in

[29] The year 1999 has the most observations per year in the data set and the NASDAQ had its ten-year peak then, while in 2002 the NASDAQ considerably dropped because of the burst of the ICT bubble.

the respective years. Again, X is the vector of firm characteristics in 1999 while Y is the vector of different financial innovation indicators. I use feasible GLS estimation with heteroskedastic error terms ϵ in the regressions. FI measures are averaged over the period 1990 to 1999 because this captures overall innovative activity per firm. Table 7 provides the results which suggest that more innovative firms face higher profitability declines during distress. The significantly negative sign on γ is consistent with the *innovation-fragility view* and suggests that firms with higher FI suffered more in a crisis.

Table 7: Comparison of Profitability Changes

	(1) Δ(ROA)	(2) Δ(ROE)	(3) Δ(Opprof)
Log of assets	0.044***	-0.329***	-0.279***
	(0.002)	(0.008)	(0.019)
EBITDA/revenues	0.010***	-0.008	
	(0.003)	(0.011)	
Leverage ratio	-0.152***	1.190***	0.675***
	(0.004)	(0.029)	(0.047)
FI by others in 2-digit zip code	-0.040***	0.041***	-0.150***
	(0.005)	(0.002)	(0.016)
Innovations (avg.)	-0.087***	-0.315***	-1.634***
	(0.006)	(0.021)	(0.178)
Patents (avg.)	-0.511***	0.366***	-1.696***
	(0.028)	(0.060)	(0.543)
Applications (avg.)	0.249***	-0.223***	0.751**
	(0.018)	(0.037)	(0.302)
Controls	Y	Y	Y
Constant	Y	Y	Y
Observations	1,202	1,201	1,196
Number of firms	1,202	1,201	1,196
R-squared	0.044	0.048	0.023

Notes: See Table A1 in the Appendix for definitions of the variables. Count data on innovations comes from the Wall Street Journal, the Factiva database or the US Patent and Trademark Office, collected by Lerner (2006). FI measures are averaged over the period 1990 to 1999. All financial data is in million 2002 US Dollars and comes from Compustat. In column 1, I use the change in ROA as dependent variable, in column 2, I use the change in ROE as dependent variable, and finally, in column 3, I use the change in operational profitability as dependent variable. In all regressions, I include firm characteristics as controls and a constant but suppress their coefficients in the tables. Control variables include firm age, cash equivalents, employees, retained earnings, shareholders' equity, preferred stock and long-term debt (all as ratios relative to assets or logarithms). Robust standard errors are clustered at firm-level and presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

6 Conclusion

In this paper, I evaluate the relationship between financial innovations and the fragility of financial institutions. Theoretical literature provides strong evidence for why financial crises exist and why firms engage in producing financial innovations. A recent strand of research tries to combine both areas and analyzes the impact of innovative activity of financial agents in a competitive framework. Particularly, this mostly theoretical literature links profit volatility to innovative activities and predicts a positive relationship. That is, the degree of innovation negatively affects firm stability.

I base my analysis on a unique data set that counts financial innovations in the USA between 1990 and 2002 provided by Lerner (2006) and augment it by performance and stability measures. Then, I build on empirical frameworks by Beck et al. (2012) and others to quantitatively assess the so called *innovation-fragility view* on a firm level. I can show that a larger degree of innovation positively (negatively) affects firm fragility (stability) after controlling for the underlying firm characteristics. A couple of extensions to the initial model show that my results are quite robust. Different modifications of the innovation measures yield the same outcomes. Furthermore, I use different fragility parameters measuring profitability, capitalization, activity risk and risk of insolvency and find that the results support my argumentation. In addition, firms with higher pre-crisis FI face higher losses during a period of financial crisis. Overall, my analyses support the *innovation-fragility view.*

Further research could include applying VAR models that take greater account for the persistence in firm characteristics and causality. Expanding the time dimension may make the analysis more robust while cross-country comparisons could provide policy recommendations. Additionally, insights into the dynamics of innovative activity could be deduced from a structural approach to modelling FI.

Appendix

Table A1: Overview of Variables, Definitions and Sources

Variables	Definitions	Sources[30]
Financial innovation measures		
Applications	Patent applications counted per firm in a year.	US PTO[31], collected by Lerner (2006)
Applications-wt	Weighted patent applications per firm in a year where the sum of 1 (count) is divided among the firms mentioned in the article about the innovation.	US PTO, collected by Lerner (2006)
Innovations	Count of stories from newspaper articles and databases on innovations per firm in a year.	WSJ[32] and FD[33], collected by Lerner (2006)
Innovations-wt	Weighted count of innovations (as above).	WSJ and FD, collected by Lerner (2006)
Innovations-ab	Count of only major innovations where Lerner (2006) applies a three-part classification scheme (A,B,C).	WSJ and FD, collected by Lerner (2006)
Innovations-wt-ab	Weighted count of major innovations (as above).	WSJ and FD, collected by Lerner (2006)
FI by Others	Number of financial innovations in the same year by other firms with headquarters in the same two-digit zip code as the firm.	WSJ and FD, collected by Lerner (2006)
Patents	Count of patents granted to a firm in a year with respect to the financial services area.	US PTO, collected by Lerner (2006)
Patents-wt	Weighted count of patents (as above).	US PTO, collected by Lerner (2006)

[30] I make use of the data set constructed by Lerner (2006) for which he draws on various data sources. In addition, I define and compute additional factors, which were previously not used, for my empirical investigation. All financial data is in million 2002 US Dollars.
[31] US Patent and Trademark Office
[32] Wall Street Journal
[33] Factiva database

Financial Institution's performance measures		
EBIT	Earnings before interest and taxes per firm and year.	Compustat
EBITDA	Earnings before interest, taxes, depreciation and amortization per firm and year.	Compustat
Net Income	Net income of a firm in million 2002 USD per year.	Compustat
Opprof	Operational profitability constructed as EBITDA / revenues (opprof = EBIT / revenues, whenever EBITDA is unavailable).	computed from Compustat data
Ret. Earnings	Retained earnings in million 2002 USD per firm in a year.	Compustat
ROA	Return on assets constructed as net income / assets.	computed from Compustat data
ROE	Return on equity constructed as net income / shareholders' equity.	computed from Compustat data
Financial Institution's stability measures		
CAR	Capital-asset ratio constructed as shareholders' equity / assets.	computed from Compustat data
Δ(Opprof)	Difference between operational profitability in 2002 and 1999.	computed from Compustat data
Δ(ROA)	Difference between return on assets in 2002 and 1999.	computed from Compustat data
Δ(ROE)	Difference between return on equity in 2002 and 1999.	computed from Compustat data
σ(ROA)	Standard deviation of ROA for each agent calculated over the sample period.	computed from Compustat data
σ(ROE)	Standard deviation of ROE for each agent calculated over the sample period.	computed from Compustat data
Sharpe	Sharpe ratio constructed as ROE / σ(ROE). Larger values imply less excessive risk for a certain return.	computed from Compustat data
Z-score	Index of bank solvency constructed as (ROA+CAR) / σ(ROA). Higher Z-score implies lower probability of failure.	computed from Compustat data

Other agent-level variables		
Age	Age of firm in relation to its foundation or IPO.	Compustat
Assets	Total assets of each financial institution in million 2002 USD per year.	Compustat
Cash equiv	Cash equivalents in million 2002 USD per firm in a year.	Compustat
Emp	Employees per firm and year.	Compustat
HHI	Herfindahl-Hirschman Index defined as the sum of squared shares of revenues oer firm to total revenues per year, i.e. HHI = $\Sigma_i^N(\text{revenues}_i/\text{total revenues})^2$ per year.	computed from Compustat data
Leverage	Ratio of the book value of a firm's long-term debt to total capitalization (book value of long-term debt and preferred stock and the market value of common stock).	Compustat
Lt. Debt	Long-term debt in million 2002 USD per firm in a year.	Compustat
MV-common	Common market value in million 2002 USD per firm in a year.	Compustat
Pref. Stock	Preferred stock in million 2002 USD per firm in a year.	Compustat
R&D	Expenditures per firm for research and development in million 2002 USD in a year.	Compustat
Revenues	Revenues in million 2002 USD per firm in a year.	Compustat
Sh. Equity	Shareholders' equity in million 2002 USD per firm in a year.	Compustat

Table A2: **Spearman Correlation Coefficients of FI measures and Z-scores of firms**

	Log of z-score	**Innovations**	**Weighted counts of innovations**	**Only major innovations**	**Weighted major innovations**	**Patents**	**Weighted counts of patents**	**Applications**	**Weighted counts of applications**	**R&D ratio**	**FI by others**
Log of z-score	—										
Innovations	-0.0417***	—									
Weighted count of innovations	-0.0417***	1.0000***	—								
Only major innovations	-0.0338***	0.8397***	0.8390***	—							
Weighted major innovations	-0.0338***	0.8397***	0.8390***	1.0000***	—						
Patents	-0.0707***	0.1459***	0.1458***	0.1272***	0.1272***						
Weighted count of patents	-0.0707***	0.1459***	0.1458***	0.1272***	0.1272***	1.0000***	—				
Applications	-0.0561***	0.1213***	0.1212***	0.1087***	0.1088***	0.4428***	0.4428***	—			
Weighted count of applications	-0.0561***	0.1213***	0.1212***	0.1087***	0.1088***	0.4428***	0.4428***	1.0000***	—		
R&D ratio	-0.2158***	0.1004***	0.1003***	0.0818***	0.0818***	0.3431***	0.3431***	0.2953***	0.2953***	—	
FI by others	-0.0187***	-0.0336***	-0.0337***	-0.0270***	-0.0271***	-0.0168	-0.0168	-0.0083	-0.0083	-0.0208***	—

Notes: *** p<0.01

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