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Park, Kay Sun

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SOLBJERG PLADS 3
DK-2000 FREDERIKSBERG
DANMARK

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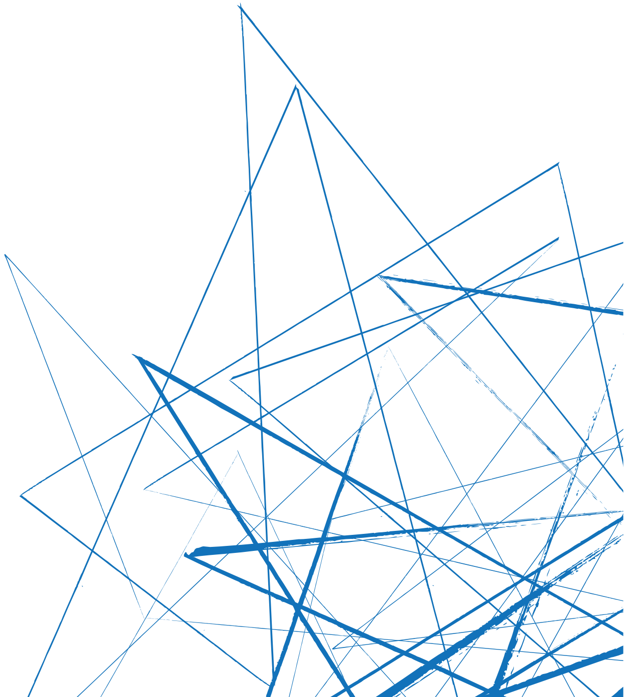

THREE ESSAYS ON FINANCIAL ECONOMICS

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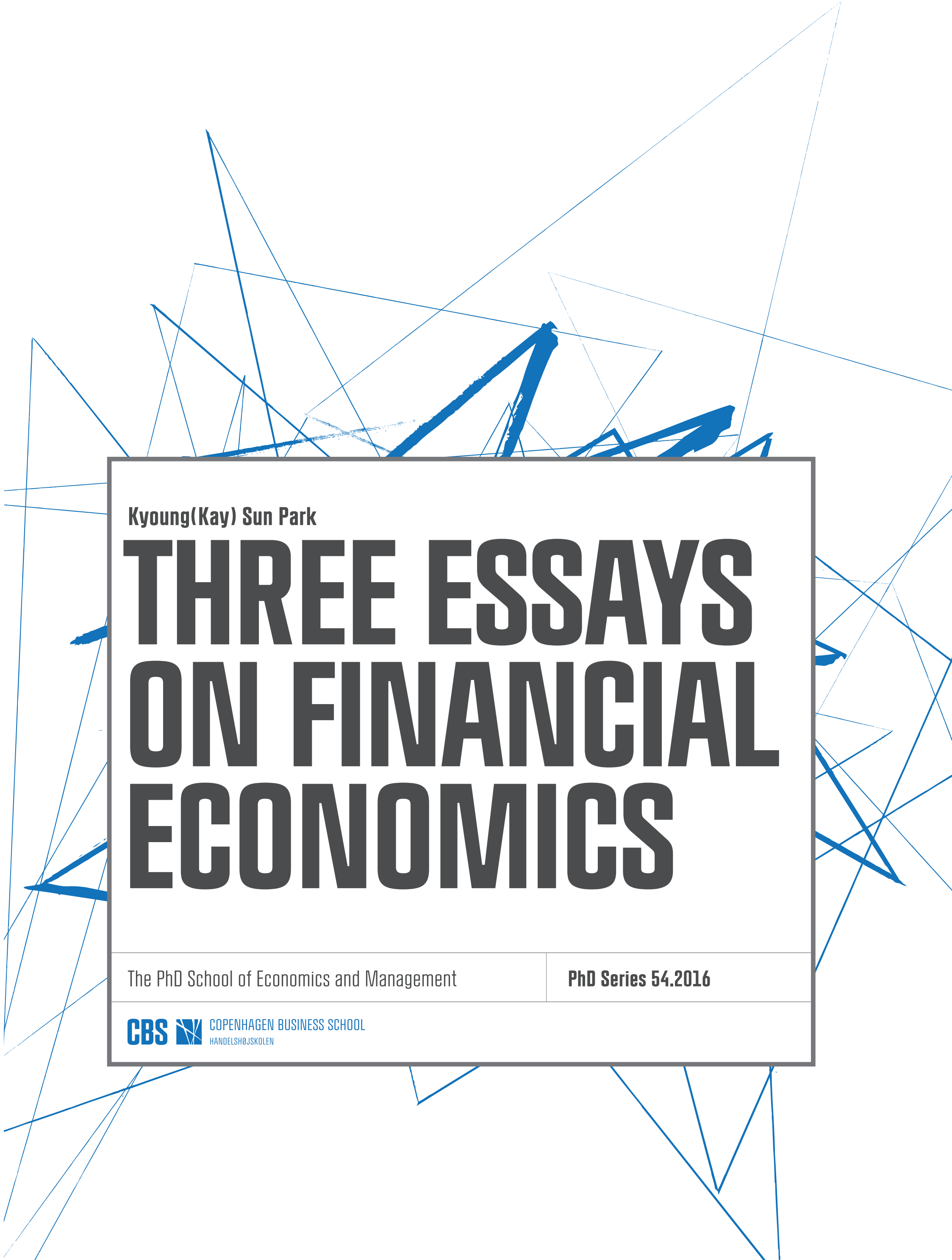

Kyoung(Kay) Sun Park

THREE ESSAYS ON FINANCIAL ECONOMICS

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Three Essays on Financial Economics

Kyoung(Kay) Sun Park

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Preface

All of work presented henceforth was conducted for my Ph.D. studies at the Department of Finance, Copenhagen Business School. The thesis consists of three essays that cover different aspects of financial economics and each essay is independent and self-contained. Chapter 1 was inspired by Kristian Miltersen and Walter Torous's unpublished theoretical work. I reinterpret the theory, implement it into an empirical setting and find the evidence to support it. Chapter 2 has been undertaken by Kristian Miltersn and myself together. We developed research ideas in discussing the issues after the recent financial crisis 2007-2009. We worked together in modelling and solving the questions. Kristian has especially contributed in interpreting our analysis and results. Finally, I was in charge of presenting the current version of paper in putting all together. Chapter 3 is the joint work with Seong-Hoon Kim. I was a lead investigator; developing research questions, putting them into an empirical framework, actively collecting data, and positioning our work in extant literature. Seong-Hoon Kim has contributed to implement STVAR in our empirical examination, furthermore presenting VAR results, writing-up the implications.

Acknowledgment

First and foremost, I wish to thank my supervisor, Kristian Miltersen. You have been a great adviser and a wonderful friend. I could not have found someone better for getting me though Ph.D experience and letting me have the freedom to explore the world of Finance. I am proud of having you as my great mentor.

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I am also hugely appreciative to Seong-Hoon Kim, especially for sharing his macroeconomics expertise as my coauthor, and for encouraging me all the time as my husband. A special thanks to my family. Words can not express how grateful I am to my mother, and father for all of the sacrifices that they have made on my behalf. Finally, I would like to thank and hug my sweet girl, Curie; she has been greatly helped me for my Ph.D years; always cheering me up.

Introduction

Practitioners in finance have been trying to either maximize their fortunes or minimize any unlucky outcomes;say, *Beat the market*. The uncertainty is always something to fear or to overcome in financial market in order to beat the market. The price of assets seems unpredictable in a short-time interval, though academics consider market price would stay at equilibrium in the long-run, as reflecting fundamentals in the end. As “Efficiency of Financial Market” says; price of assets reveals all relevant information. The continuous-time random walk is successfully taken as close as tracking down the asset price movements. Moreover, a regime-switching between good versus bad state abruptly occurs over the business cycle (or the financial cycle). Hence, two key theoretical devices used to model risk in finance are first, to acknowledge that we see the movements of asset price micmic a random walk in a continuous manner and second, to acknowledge that we observe the state of a world seems to switch from one to another regime. In this thesis, I investigate how time variation in risks and uncertainty affects firm’s funding decisions as well as market’s aggregates movements.

Nevertheless, it has been an important question how firms decide their external financing to undertake NPV projects. Modigliani and Miller present the famous irrelevant theorem; in a frictionless world, the type of external financing does not matter. Later, Miller complements his irrelevance proposition with a tax argument. The trade-off between tax benefits and bankruptcy costs optimally determines firm’s leverage. Assuming that the firm’s cash flow mimics a random walk, this helps a firm to rebalance its leverage in a continuous manner in order to manage its default risk. A firm with higher volatility of earnings appreciates for its ability to adjust its debt level as long as it can afford its issuing costs of new debts. Short-term debt is considered to mitigate in agency conflicts in investment decisions; furthermore it enables its downward adjustment of leverage when it hit by negative shocks, by letting them matured. In this way, a firm historically issued short-term debt can issue more debts ceteris paribus. We find the evidence from U.S. industrial firm's bond issuance data.

Our second question starts with a firm susceptible to downward systemic risks, for instance, a bank. Bank's failure in historical perspectives goes along the financial cycle as well as its risk-taking behaviour. Once its risk-taking behaviour might cause its failure, the consequence of bank failure should be internalized within capital market in this regards. After the recent 2007-2009 financial crisis, regulatory agencies discipline banks to implement a loss-absorbing mechanism in bank's balance sheet by issuing contingent capitals;Cocos. We model the specialty of firms associated with the business cycle with a regime-switching framework. We found that the state contingent coupon rate mitigates a firm's liquidity shortage in times of bad state of economy. Finally, we are interested in the interactions among aggregate financial index; margin, S&P 500 price, and aggregate liquidity. Conditional on the state of uncertainty (or risk aversion), three variables reinforce one another into a feedback loop. A growing literature assures that financial cycle exists and VIX, a measure of S&P 500 Option Volatility, works well as a good indicator of this cycle. The financial cycle has a longer time span than the business cycle and the recession after the collapse of financial boom seems not only more severe but also sluggish to recover from it. Minsky illustrates how the unstable nature of financial system is developed by itself. Minsky's Financial Instability Hypothesis state that there are three agents in the market; Hedger, Speculator and Ponzi investor. While in prolonged good states, Hedgers are engaged in Speculation or Ponzi scheme, to make matters worse, authorities controlling inflation in good state leads their profits to evaporate. In the end, the asset bubble collapses; Minsky moment. We empirically investigate how the nature of financial stability and instability is revealed in their interplay; among funding constraint, market liquidity, and market risk and how its instability mechanism emerge along with the financial cycle.

Summary

English

Essay 1 : Financial Flexibility and Debt Maturity

We examine how firms determine their maturity and leverage. Using simultaneous equations of maturity and leverage regression, we find that (1) firms with high volatility of earnings tend to issue short-term debt; and (2) firms with debt of shorter maturity tend to have higher leverage. These results imply that a short maturity benefits a firm in respect of financial flexibility under volatile business environments, while at the same time the financial flexibility contributes to a firm's debt capacity. Our findings support the dynamic capital structure model in which a firm simultaneously adjusts debt maturity and leverage over the joint space of two trade-offs; one between tax benefits and bankruptcy costs, and the other between flexibility benefits and issuing costs. And the results rationalize in part the observed capital and maturity structure of financial institutions for the pre-crisis period.

Essay 2: Sharing Downside Risks: Contingent Coupon Bonds

We propose and solve a model of optimal capital structure in which the growth rate and volatility of the earnings shift between different states. We show that a firm can enter coupon payment contracts on contingency; paying higher coupon in Good state and lower in Bad state. We show that this type of security allows for an effective risk-sharing between a firm and investors. Our results suggest that contingent coupon bonds can help a firm be resilient hit by systemic downside risks.

Essay 3: Liquidity Spirals over Moving Uncertainty: Evidence from US Financial Aggregates

We study how the instability of financial markets is related to uncertainty. We take the financial aggregate data from US stock markets into a VAR model, allowing uncertainty to continuously change behind. We find that margin requirements, market liquidity, asset prices all mutually destabilize only in the times of high uncertainty. Related findings are that in the times of low uncertainty, (1) margins and market liquidity rather stabilize each other; (2) reinforcement between margins and asset prices are much delayed in effect; and (3) asset prices and market liquidity react little each other. In brief, uncertainty fluctuations are crucial to understanding how and when liquidity spirals turn on and off in US stock markets.

Danish

Essay 1: Finansiel Fleksibilitet og modenhed

Vi undersøger, hvordan virksomheder bestemmer deres løbetid og gældsgrad. Ved at bruge simultaneousequations regressions metoden på løbetid og gældsgrad, finder vi, at (1) virksomheder med høj volatilitet i indtjeningen foretrækker at udstede kortfristede gæld; og (2) virksomheder med gæld med kortere løbetid kan tillade sig selv en højere gældsgrad.Disse resultater indebærer, at kort løbetid på gælden gavner en virksomhed i formaf finansiel fleksibilitet i et usikkert erhvervsmiljø, samtidigt bidrager den finansielle fleksibilitet til at øge virksomhedens gældskapacitet.Vores resultater understøtter den dynamiske kapitalstrukturmodel, hvor en virksomhedsimultant kan justere gældsgrad ogløbetidmed det formål at optimere inden for flg. to afvejninger:den første afvejning mellem skattefordele og konkurs omkostninger, og den anden mellem fleksibilitetsfordele og gældsudstedelsesomkostninger. Resultaterne rationaliserer delvistobserverede løbetids- og gældsgradsvalg for de finansielle institutioner for perioden før krisen.

Essay 2: Deling negative risici: Betingede kupon-obligationer

Vi foreslår og løser en model for optimal kapitalstruktur, hvor vækstraten og volatiliteten af indtjeningen skifter mellem forskellige tilstande. Vi viser, at en virksomhed foretrækker atindgå betingede kuponbetalingskontrakter baseret på den ukendte tilstand,

således at den betaler højere kupon i den gode tilstand og lavere kupon i den dårlige tilstand.Vi viser, at denne type kontrakt giver mulighed for en effektiv risikodeling mellem virksomheden og densgældshavere.Vores resultater indikerer, at obligationer med tilstandsafhængige kuponniveauer kan afhjælpe konsekvensen af, at en virksomhed bliver ramt af systemiske down-side-risiko.

Essay 3: Likviditet spiraler end Moving Usikkerhed: Beviser fra amerikanske Financial Aggregates

Vi studerer hvordan ustabilitet på de finansielle markeder er relateret til usikkerhed.Vi analyserer de samlede finansielle data fra amerikanske aktiemarkeder i en VAR model, som tager højde for at usikkerheden kan ændre sig løbende kontinuerligt i tiden.Vi finder, at marginkrav, markedslikviditet og aktiepriser kun kan destabilisere simultant i tider med stor usikkerhed.Relaterede resultater er, at i tider med lav usikkerhed,(1) vil marginkrav og markedslikviditet snarere stabilisere hinanden;(2) sammenhængen mellem marginkrav og aktiepriser er meget forsinkede; og(3) aktiepriser og markedslikviditet reagerer kun svagt af hverandre. Kort fortalt, udsving i usikkerheden er afgørende for at kunne forstå, hvordan og hvornår likviditetsspiraler kan opstå og forsvinde i amerikanske aktiemarkeder.

Chapter 1

Financial Flexibility and Debt Maturity

We examine how firms determine their maturity and leverage. Using simultaneous equations of maturity and leverage regression, we find that (1) firms with high volatility of earnings tend to issue short-term debt; and (2) firms with debt of shorter maturity tend to have higher leverage. These results imply that a short maturity benefits a firm in respect of financial flexibility under volatile business environments, while at the same time the financial flexibility contributes to a firm's debt capacity. Our findings support the dynamic capital structure model in which a firm simultaneously adjusts debt maturity and leverage over the joint space of two trade-offs; one between tax benefits and bankruptcy costs, and the other between flexibility benefits and issuing costs. And the results rationalize in part the observed capital and maturity structure of financial institutions for the pre-crisis period.

1.1 Introduction

In the traditional capital structure models, debt maturity is irrelevant as is exogenously specified whether perpetual or fixed over time (Leland, 1994; Leland and Toft, 1996; Goldstein, Ju, and Leland, 2001). However, these traditional models are of limited empirical relevance. Not only debt level but also debt maturity moves over business cycles. The value weighted average of debt maturity across US firms tends to be lengthened in good times and shortened in bad times (Mian and Santos, 2012). Financial firms also shorten their loan maturity in market downturns as observed during the recent financial crisis (Gorton, Metrick, and Xie, 2015). Maturity has even real effects: Non-financial firms with debt happening to mature in a middle of a financial crisis tend to cut down investment more heavily than others whose debt remains to mature at later dates (Almeida et al., 2009). In this world, a firm's decision of how much levered is not separable from its decision of how long levered.

However, at the beginning, what made debt maturity relevant to corporate financial decision? A body of maturity structure models developed over the last decade stand on one common premise: Firms do value financial flexibility or capability to rebalance their capital structure over time. Provided that the financial flexibility is inherent in the refinancing frequency, firms will finance themselves short-term debt for various reasons. For example, they can use it to easily reoptimize their leverage ratio in response to the changes in market interest rates (Ju and Ou-yang, 2005); to mitigate the conflict between different stakeholders on making new investment (Childs, Mauer, and Ott, 2005); to prevent the remaining debt-holders from free-riding when paying back a fraction of the existing debt (Miltersen and Torous, 2007); to automatically reduce debt level when other means of lever-down is more costly (Dangl and Zechner, 2016); to keep room for choice of default timing on debt (He and Milbradt, 2016); and so on. Despite its popular invokedness in theoretical modelling, the flexibility argument is rarely examined in data.

The first contribution of the present paper lies toward this direction of empirical analysis. We trace leverage dynamics in data and find that firms with debt of shorter maturity are much faster in rebalancing their leverage ratios: In terms of time taken until crossing up/down the initial leverage level after hit by bad/good shocks, firms belonging to the shortest-maturity quintile need 1 year whereas those belonging to the longest-maturity quintile require more than 4 years. The financial flexibility works built in debt maturity.

Securing the evidence for the flexibility-in-maturity, we then move onto comprehensive tests of the theory of optimal maturity and capital structure with particular reference to Miltersen and Torous (2007). Miltersen and Torous (2007) work out a firm's optimal (value-maximizing) maturity structure and leverage ratio as a function of its earning volatility along with other characteristics constituting the joint space of two trade-offs; one between tax benefits and bankruptcy costs, and the other between flexibility benefits and issuing costs. Although the double trade-offs are found common among the recent theoretical works, Miltersen and Torous (2007) provide a clearer framework that straightforwardly facilitates studying firm heterogeneity in debt maturity as a function of observable business characteristics.

We carry out cross-sectional analysis with a complete range of US corporate data from FISD, DealScan, and Compustat. How much levered and how long levered are endogenously determined upon the two trade-offs. We take into account the endogeneity problem by setting up simultaneous regression equations for maturity and leverage with instruments.

We depart from earlier studies by giving the credit to the fact that maturity is not the only way the financial flexibility can embody in. As documented by Roberts and Sufi (2009), 90% of bank loans made to publicly listed US firms over 1996-2005 have been renegotiated prior to their stated maturity. This implies that where debt contracts are renegotiable, the flexibility in maturity is replaced with the flexibility in renegotiability. Similarly, for debts having option-like-features, it will be replaced with the flexibility in exercisibility. Thus we take into consideration debt characteristics by groupping into exercisibles (callable, convertible, redeemable bonds etc.), renegotiables, and straights. Our baseline analysis uses straight public bond data as is most appropriate for test of Miltersen and Torous (2007)'s theory. In addition, we use the maturity of incremental debt issues rather than the average maturity of all liabilities on a firm's balance sheet. As robustness exercises to check whether maturity decisions critically depend on its flexibility content, we also repeat the same ananlysis by different debt types and by different maturity measures.

Our key findings include that (a) firms facing more volatile earnings tend to issue debt with shorter maturity; (b) firms with shorter maturity debt tend to lever themselves up to higher leverage; (c) firms facing more volatile earnings tend to make lower leverage; (d) firms with lower issuance costs tend to issue debt with shorter maturity. All these results support the theoretical predictions held *ceteris paribus* in Miltersen and Torous (2007).

The first two results particularly highlight the flexibility-in-maturity and its role in forming optimal maturity structure and leverage ratio given business environment. Result (a) makes sense in that intuitively, the value of the financial flexibility will be more appreciated by firms operating under more volatile business environment. It is also consistent with Stohs and Mauer (1996)'s observation that larger and less risky firms have longer-term debt while firms with more earning surprises have more short-term debt. The cross-sectional result also casts a clear implication on the cyclical behavior of debt maturity: As demand for the financial flexibility increases when marketwide uncertainty rises, firms are likely to shorten debt maturity on average during the times of financial turmoil. This is exactly what documented by Mian and Santos (2012) and Gorton, Metrick, and Xie (2015).

Result (b) is also immediate from the flexibility-in-maturity argument. To the extent that the financial flexibility helps increase firm value, it can potentially contribute to a firm's debt capacity and thus lead to a higher leverage ratio. This may be because the flexibility enables a firm to hedge bankruptcy risk in bad states by reducing debt level without interference from various stakeholders of different interests (Miltersen and Torous, 2007; Dangl and Zechner, 2016) and/or to capture more tax shields by frequent repricing of debt (Childs, Mauer, and Ott, 2005; Ju and Ou-yang, 2005). The result is consistent with Barclay, Marx, and Smith (2003) and Billett, King, and Mauer (2007).

By the other two results, (c) and (d), we also confirm the traditional wisdom established in the literature with respect to the two theoretical pillars of the dynamic capital structure models. Result (c), in relation to the first trade-off, indicates that firms faced by larger bankruptcy risk take lower leverage while giving up tax benefits. This relation is repeatedly confirmed in the literature (for example, among some recent works, Johnson, 2003; MacKay, 2003; Billett, King, and Mauer, 2007; Brockman, Martin, and Unlu, 2010; Harford, Klasa, and Maxwell, 2014).

Result (d) supports the second trade-off, which holds between flexibility benefits and issuance costs. Intuitively, high direct issuance costs impede frequent issuing of bonds and thus firms subject to higher issuance costs will be likely to issue debt with longer maturity at the opportunity cost of foregone financial flexibility. This result is in the same line with the early literature on underwriting market (for example, Melnik and Plaut, 1996; Gande et al., 1997).

Finally, we do robustness checks against the role of flexibility benefits in maturity decisions using different types of corporate debt. We find that for renegotiable private credit agreements, maturity and leverage tend to force each other toward the same direction. Similar results follow when taking average over all liabilities without discerning debt types whether exercisible with implicit and explicit option. These results imply that once flexibility benefits removed from maturity structure and replaced by other characteristics, expected transaction costs will take larger weitght in the second trade-off and be more likely to lead to some bulkiness in both leverage and maturity. Therefore, failure to discern and control flexibility content out of debt types and aggregation methods can potentially mislead one in examining corporate maturity policy. This is a third contribution the paper adds to the literature as it helps reconcile a body of previous empirical studies seemingly contradicting one another.

The rest of this paper is organized as follows: Section 2 describes data and empirical methods for identification and estimation. Section 3 presents the results for leverage dynamics and cross-sectional variation, and thereby establishes that debt with short maturity benefits firms in respect of flexible capital structure and contributes to debt capacity and firm value. Section 4 and 5 repeat the same analysis employing different samples, 'contaminated' in a sense of comprising either renegotiable or exercisible debt. Bringing all these results on leverage dynamics (Sections 3.1 & 4.1 & 5.1) and cross-sectional variations (Section 3.2 & 4.2 & 5.2) from different samples, we conclude that maturity and leverage are as cohesively related in data as they are in theory.

1.2 Empirical Methods

1.2.1 Data and Samples

We construct data set from the Fixed Income Security Data (FISD), Thomson-Reuter Loan Pricing Corporation Deal Scan (DealScan), and Standard and Poor's Compustat (Compustat). We start with bond issuance data drawn from the Mergent FISD, which covers issue details on publicly offered US corporate bonds, and obtain issuance information including issuing dates, maturity, offering amount, offering yield, coupon frequency, coupon type, and other relevant features. We also draw bank loan data from DealScan, which includes a comprehensive historical information on loan pricing, contract details, terms and conditions. We obtain balance sheet information from Compustat North America Fundamental Annual and Quarterly files.

We then match the FISD bond issuance data with the Compustat balance sheet data. We call the merged one “FISD sample”. We also match the DealScan bank loan data with the Compustat balance sheet data, and call it “DealScan sample”. Notice that Compustat database contains its own corporate bonds. We thus consider another sample in which debt maturity and balance sheet information are all drawn from Compustat alone. We call it “Compustat sample”. We submit each of the three samples to separate examination for better identification. We take “FISD sample” for our baseline analysis and the other two for further checks.

Our main interest is to see whether firms behave in data as they do in theory of the dynamic capital structure model where a firm simultaneously adjusts debt maturity and leverage over the joint space of two trade-offs; one between tax benefits and bankruptcy costs, and the other between flexibility benefits and issuing costs. However, in practice, maturity is not the only way the financial flexibility can embody in. Where debt contracts are expected to renegotiate, the flexibility in maturity may be replaced with the flexibility in renegotiability. Where debts have option-like-features, the flexibility in maturity will be dwarfed by the flexibility in exercisibility.

We have the FISD sample including straight public bonds only, while taking out callable, convertible, redeemable bonds and as well as private credit agreements. The DealScan sample consists of bank loans made between financial institutions and publicly listed US firms. The Compustat sample is a mixed pot of all corporate liabilities in firms’ balance sheet. For all these samples, financial firms are excluded that fall into the standard industrial classification (SIC) codes from 6000 to 6999. We also require firms to have at least three years of consecutive observations. We winsorize the top and bottom 1% in values of each variable to minimize the effect of outliers. The combined data set covers the period from 1987 through 2010.

We define variables following the existing literature, as listed and described in Table1.1. We will provide further details where needed as we proceed. But for now, it may be noteworthy that maturity measures differ between the samples. As well claimed by Guedes and Opler (1996), it is better suited for testing of the theory to examine the maturity of incremental debt issues rather than the maturity of all liabilities on a firm’s balance sheet since it is not easy to control all determinants of debt maturity that may substantially shift. The FISD sample records new bond issuance. The DealScan sample records bank loan *per se*. Thus for these two samples, we follow Guedes and Opler (1996) and define maturity as difference between stated maturity date and issuance date. For the Compustat sample, we measure a firm's debt maturity by the weighted average of remaining life of all outstanding long-term debts on its balance sheet.

1.2.2 Dynamic Analysis

Our empirical investigation is carried out with particular reference to Miltersen and Torous (2007) among the recent developments in the literature. In their theory, debt of shorter maturity yields flexibility benefits because it can help reduce conflicts of different interest between equity-holders and debt-holders. When a firm's business conditions improve, the debt-holders and equity-holders have a common interest in re-balancing the firm's capital structure and creating new debt. In contrast, when its business conditions worsen, a free-riding of the remaining debt-holders makes it sub-optimal for equity-holders to reduce the amount of debt by partly paying back debt. In their model, therefore, the firm can reduce its outstanding debt only by issuing finite maturity debt and waiting for it to mature mechanically. The more of its debt mature per unit of time, the larger room the firm secures for new (junior) debt. For example, even when it has to reduce debt level by 1 unit l in response to a bad shock, the firm can issue 1 unit of new debt if 2 units of old (senior) debt were previously scheduled to be paid back. This flexibility benefits the firm but comes at a cost. Debt issuing is costly. Miltersen and Torous (2007) show the existence of an optimal maturity structure which counterbalances issuing costs as well as tax benefits and bankruptcy costs.

The model gives dynamic and cross-sectional implications. On dynamic side about about how firms should behave over time, the model predicts that firms who experience a bad shock to their earnings cannot easily adjust their leverage down to their new optimal level and will have to wait for their existing debt to mechanically mature. This re-optimization process will be fast for firms who have previously chosen a relatively short maturity structure, whereas it will take long time for those who have previously chosen a long maturity structure.

To test this dynamic implication, we first sort all firms by their stock returns. This procedure keeps a roughly equal number of firms in each quintile, holding calendar year and the number of firms constant. We then divide them into five bins on the

Table 1.1: Variables: Definition and Construction

Note: The variables in this table are either drawn or constructed from Compustat, CRSP, and FISD. The numbers in the parenthesis, (#), correspond to the data item numbers from the Compustat Annual Industrial file.

Variable	Name	Construction
Total Assets	AST	Assets(6), total book value
Firm Size	SIZE	AST in logarithm
Preferred Stock	PRFS	Maximal value out of {Preferred Stock's Liquidating Value(10), Redemption Value(56), Carrying Value(130)}
Book Value of Equity	EQB	AST - Total Liabilities(181) - Deferred Taxes & Tax Credit(35) - PRFS
Total Debt	DEBT	Debt in Current Liabilities(34) + Long-Term Debt(9)
Book Leverage	LEVB	DEBT/AST
Market Value of Equity	EQM	Stock Price(199)×Common Shares Used to Calculate Earnings per Share (54)
Market Leverage	LEVM	DEBT/{DEBT + EQM}
Profitability	PROF	Operating Income Before Depreciation(13)/AST
Tangibility	TAN	Net Property, Plant, and Equipment(8)/AST
Market-to-Book	MBR	{EQM + DEBT + PRFS - Deferred Taxes &Tax Credit(35)}/AST
Cash Holding	CASH	Cash and Short-Term Investments(1)/DEBT
Time-to-Maturity	MAT	Difference between year in maturity and an offering year (Both FISD and DealScan sample)
DD3/DLTT	MAT	A fraction of total long-term debt due in next three years excluding maturing debt within a year (DD2(91)+DD3(92)-DD1(44)), scaled by total long-term debt(DLTT(142)) (Compustat sample)
Gross Spread	ISSU	Difference between the prices which issuers receive for their securities and the prices at which investors pay (FISD sample)
AllInUndrawn	ISSU	Sum of commitment and annual fee (DealScan sample)
Equity Return	RETN	Cumulative monthly stock returns for a year from CRSP monthly files
Asset Volatility	VOLT	Std dev of RETN scaled by EQM/{EQM + Long-Term Debt(9) + 1/2*Debt in Current Liabilities(34)}
Z-score	ZSCO	3.3×(178)/(6) + 1.2×[(4)-(5)]/(6) + (12)/(6) + 0.6×(199)×(25)/[(9)+(34)] + 1.4×(36)/(6)
Z-score Dummy	ZSCD	Equals 1 if Z-score is greater than 1.81, and 0 otherwise

basis of debt maturity. In total, we have 25 bins by their performance and debt maturity in each year from 1987 through 2010. We keep firms survived for four years in our sample, since we focus on how a firm's leverage has changed by its performance shock over some periods.

We monitor the dynamics of leverage over four-year time interval, which would tell the difference of the interaction between leverage and maturity among various maturity groups. We choose the combination of the worst performers with the shortest debt maturity in year $t = 0$ and compare them with the equivalents with the longest debt maturity in year $t = 0$. We keep tracing their leverage between a previous year and next four years with a negative(positive) shock in year $t = 0$, thereby observing a firm's dynamic adjustments of capital structure. In the same way, we look at the dynamics of leverage when a firm was hit by positive shocks. We compare the best performers having shortest maturity of debt with the those having longest maturity of debt.

1.2.3 Cross-sectional Analysis

We test the cross-sectional implications about how different firms choose different optimal maturity structures and leverage ratios. We utilize a range of estimation models; simple regression, difference in difference, and IV regression.

1.2.3.1 Simple Regression and DID

We start with running a simple regression for each of maturity and leverage, separately:

$$\text{MAT}_{i,t} = \alpha_i^m + y_t^m + \beta^m X_{i,t}^m + \epsilon_{i,t}^m, \tag{1.1}$$

$$\text{LEVM}_{i,t} = \alpha_i^l + y_t^l + \beta^l X_{i,t}^l + \epsilon_{i,t}^l. \tag{1.2}$$

where α_i^k, $k = \{m, l\}$, captures a firm or industry level fixed effect in maturity equation (m) and leverage equation (l), respectively; y_t^k is a year fixed effect in each equation; and $X_{i,t}^k$ is a vector of independent variables.

The independent variables of interests for a maturity equation, $X_{i,t}^m$, include leverage (LEVM), asset volatility (VOLT), and debt issuance costs (ISSU). The independent variables of interests for a leverage equation, $X_{i,t}^l$, include as maturity (MAT), asset volatility (VOLT), and debt issuance costs (ISSU). We measure VOLT as a levered historical equity volatility, using information from historical stock returns. We proxy ISSU using gross spread, which is the difference between the offered amount and the proceeds to the issuer as a percentage of the issue size. We take direct issuance costs in our analysis, hence the indirect issuance costs, such as rollover costs and liquidity risks, are not considered in our optimal framework.

We further utilize a difference-in-difference method:

$$\triangle \mathrm{MAT}_{i,t} = \alpha_i^m + y_t^m + \beta^m \triangle X_{i,t}^m + \epsilon_{i,t}^{\triangle m}, \tag{1.3}$$

$$\triangle \mathrm{LEVM}_{i,t} = \alpha_i^l + y_t^l + \beta^l \triangle X_{i,t}^l + \epsilon_{i,t}^{\triangle l}. \tag{1.4}$$

This is to control for unobserved variations among firms. We examine how changes in leverage and maturity from the end of year t–1 to the end of year t are associated with changes in independent and control variables.

1.2.3.2 Simultaneous Equations with Instruments

How much levered and how long levered are endogenously determined upon the two trade-offs. We take into account the endogeneity problem by setting up simultaneous regression equations for maturity and leverage with instruments. First, we separately specify two OLS regressions for debt maturity and leverage with instruments, and then simultaneously estimate the two structural equations by including the predicted values from the first-stage regression as explanatory variables. The 2SLS methodology accounts for any correlation between the residuals of leverage and the debt maturity models, which is caused by unobserved influences on two variables.

Our two-equation system is specified as follows:

$$\begin{cases} \text{MAT}_{i,t} & = \alpha_0^m + \beta_1^m \text{VOLT}_{i,t} + \beta_2^m \text{LEVM}_{i,t} + \beta_3^m \text{ISSU}_{i,t} + \beta_4^m \text{SIZE}_{i,t} \\ & + \beta_5^m \text{PROF}_{i,t} + \beta_6^m \text{TAN}_{i,t} + \beta_7^m \text{MBR}_{i,t} + \beta_8^m \text{CASH}_{i,t} \\ & + \beta_9^m \text{TERM}_{i,t} + \beta_{10}^m \text{ZSCD}_{i,t} + \beta_{11}^m \text{ID.MAT}_{i,t} + e_{i,t} \\ & \\ \text{LEVM}_{i,t} & = \alpha_0^l + \beta_1^l \text{VOLT}_{i,t} + \beta_2^l \text{MAT}_{i,t} + \beta_3^l \text{SIZE}_{i,t} \\ & + \beta_4^l \text{PROF}_{i,t} + \beta_5^l \text{TAN}_{i,t} + \beta_6^l \text{MBR}_{i,t} + \beta_7^l \text{CASH}_{i,t} \\ & + \beta_8^l \text{TAXD}_{i,t} + \beta_9^l \text{ACQD}_{i,t} + \beta_{10}^l \text{ID.LEV}_{i,t} + e_{i,t} \end{cases} \tag{1.5}$$

We rely on earlier empirical studies to guide our selection of instrumental variables in the simultaneous equations (Johnson, 2003, Brockman, Martin, and Unlu, 2010, Harford, Klasa, and Maxwell, 2014). The extant capital structure literature finds that expected marginal tax rate (TAXD), acquisition dummy (ACQD) and industry leverage (ID.LEV) are important determinants of leverage (Barclay, Smith, and Watts, 1995; Barclay, Marx, and Smith, 2003; Brockman, Martin, and Unlu, 2010; Billett, King, and Mauer, 2007). Nevertheless, those variables do not play any important role in determining maturity of debt. We conjecture these variables are orthogonal to the error terms and having zero coefficients in the maturity regression. Furthermore, term structure (TERM), industry maturity (ID.MAT), and financial distress dummy (ZSCD) are closely related to determine maturity but not leverage. Hence, we treat these variables as orthogonal to the error terms and having zero coefficients in the leverage equation.

1.3 Empirical Results

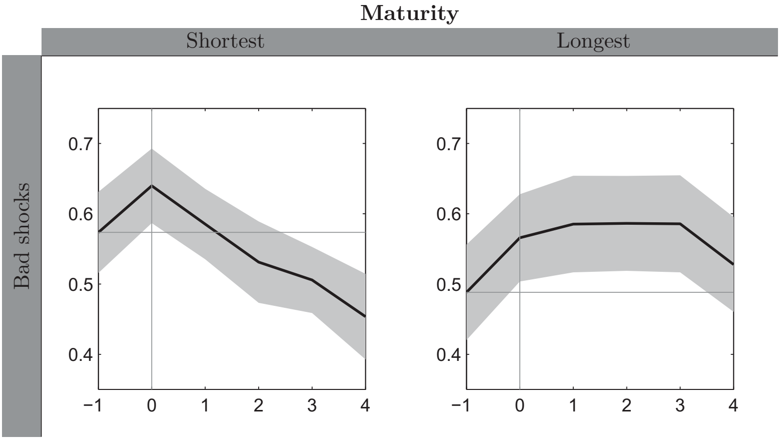
1.3.1 Leverage Dynamics

We investigate the dynamics of capital structure; whether a firm is optimally adjusting its dynamics of maturity and leverage to performance shocks over some years. A firm would optimally lever itself up once its performance is improved in order to reach its optimal leverage without conflicts between equity-holders and bond holders. With negative shock, equity holders would like to reduce a firm's debt level in order

Table 1.2: Summary Statistics of FISD sample

Note: This table presents summary statistics for our final FISD bond issuance sample.

Variable	No.Obs	Mean	Median	Std. Dev	Min	Max
Time-to-Maturity	2345	8.52	7.00	6.05	0.38	22.0
Book Leverage	2345	0.44	0.47	0.34	0.00	0.99
Market Leverage	2345	0.47	0.44	0.21	0.11	0.97
Size	2345	8.54	8.66	1.59	4.60	12.3
Cash Holding	2339	0.08	0.03	0.24	0.00	0.68
Profitability	2331	0.12	0.12	0.07	-0.07	0.34
Market-to-Book	2345	1.09	0.90	0.68	0.35	4.21
Tangibility	2341	0.46	0.45	0.25	0.03	0.91
Asset Volatility	2166	0.14	0.12	0.06	0.03	0.37
Return	2345	0.12	0.09	0.47	-0.82	1.88
Z score	2047	2.43	2.18	1.66	-1.01	8.18
Amount of Bond (M)	2345	236.4	185.0	221.5	10.0	1,400.0
Coupon	2345	8.18	7.95	2.26	0.00	15.4
Gross Spread	1996	7.42	6.83	5.27	0.00	34.7



Note: The figure shows the dynamics of leverage from $t-1$ through $t+4$ for firms from the lowest performance quintile at $t=0$, which are in turn divided into five cohorts according to their maturity structure. The two figures are for those in the shortest vs. longest quintile, respectively. The thick solid line traces the mean value of leverage ratio for each group. The shaded area represents 95% confidence interval. The light-grayed horizontal line indicates the initial ratio of leverage.

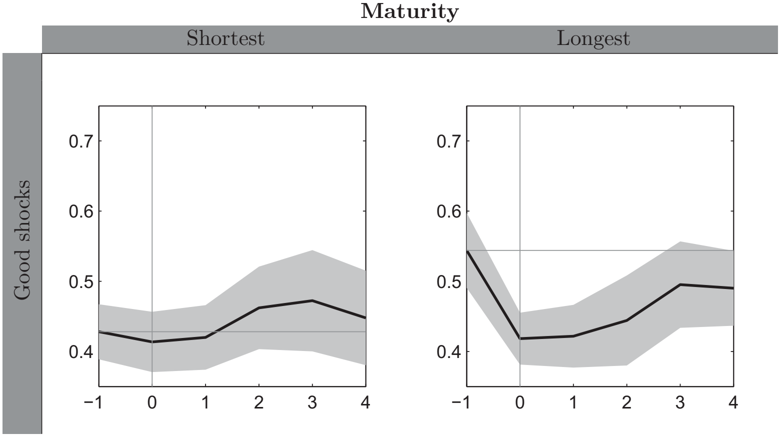
Figure 1.1: Leverage Dynamics for For Firms with Lowest Returns at Time Zero

to manage its bankruptcy probability. However, this is not easy since all benefits from restructuring go to existing bond holders. The only way is to wait for some of outstanding debt matured. A firm having historically issued debts with shorter maturity can adjust quickly its leverage hit by bad shocks while an equivalent but with longer maturity would take more time to reduce its debt level.

We select the extreme group in their performance in order to see their distinctive actions towards adjusting their leverage. With good shocks, we expect the upward adjustment is prevalent for both long and short maturity group as it is optimal for firms with the positive shocks to increase its debt capacity. With bad shocks, we expect that voluntary debt reductions are more prominent in the shortest debt maturity group while the longest debt maturity group is slower than its counterparts.

With bad shocks Figure 1.1 shows the average leverage dynamics of the shortest maturity group adjust after a negative performance shock measured by stock return, while Figure 1.2 shows the equivalent of the longest maturity group. The thick solid line traces the mean value of leverage ratio for each group. The shaded area represents 95% confidence interval. The light-grayed horizontal line indicates the initial ratio of leverage. The leverage in the worst performers in quintile with the shortest maturity has risen from year $t = 0$ to year $t = 1$ after very low equity return in $t = 0$. This follows mechanically from the reduction in the denominator of the leverage calculation (long-term debt + total equity) since the price of equity dropped. However, the leverage is readjusted quickly between year $t = 1$ and $t = 2$ but later on its speed of reduction gets slower at the end of observation year $t = 4$. As well as the lowest performance quintile with the longest maturity group has automatically raised its leverage ratio since the equity price plummeted. But it has not started to deleverage much until at $t = 3$.

With good shocks On the contrary, we examine the highest performance group with the shortest debt maturity in year $t = 0$ and compare them with the longest debt maturity group. We keep tracking their leverage between a previous year $t - 1$ and next four years $t + 4$ with a positive shock in year $t = 0$, thereby observing a firm's dynamic adjustment in its capital structure. Changes in capital structure differ from the previous analysis; its leverage ratio decreases due to an increase of equity price at the first year. Later, both groups levered themselves up, even though the



Note: The figure shows the dynamics of leverage from $t-1$ through $t+4$ for firms from the highest performance quintile at $t=0$, which are in turn divided into five cohorts according to their maturity structure. The two figures are for those in the shortest vs. longest quintile, respectively. The thick solid line traces the mean value of leverage ratio for each group. The shaded area represents 95% confidence interval. The light-grayed horizontal line indicates the initial ratio of leverage.

Figure 1.2: Leverage Dynamics for For Firms with Highest Returns at Time Zero

shortest maturity group is faster than the longest maturity one in increasing its debt level.

In conclusion, the dynamics of leverage shows that a firm with historically issued short-term debt had better to readjust its leverage than the equivalent with long-term debt when it was hit by a negative shock. Our observation confirms that voluntary debt reduction is possible for firms with with short-term debt financing (Dangl and Zechner, 2016, Miltersen and Torous, 2007), as well as it reassures an upward adjustment is optimal for both long-term debt issuers and short-term ones with positive shock (Goldstein, Ju, and Leland, 2001; Ju and Ou-yang, 2005).

1.3.2 Cross-sectional Variation

Table 1.1 provides the definitions of variables in the regression analysis. Debt maturity is defined as an amount-weighted average of time to maturity at bond issuance. Leverage is defined as either book leverage or market leverage. Book leverage is defined as total debt (the book value of long-term debt plus debt in current liabilities), divided by the book value of assets. Market leverage is defined as total debt divided by market value of equity plus total debt. We include both of these leverage variables in all of the empirical analysis for robustness. The independent variables of interest are following: asset volatility is defined as the standard deviation of equity return multiplied by market value of equity divided by market value of equity plus total long-term debt plus half of short-term debt. Size is the log of total assets. Profitability is operating income scaled by total assets. Tangibility is net property, plant and equipment scaled by total assets. Market to Book ratio is market value of equity plus total debt minus deferred taxes and investment tax credit scaled by total assets.

Simple Regression Table 1.3 reports a pooled ordinary least squares (OLS) regression results. We also employ year and industry fixed effects in order to consider variations among industry and year specific observations. Panel (b) of Table 1.3 reports the regression results with year and industry fixed effects. As various specifications of pooled OLSs are made, our empirical findings have inconclusive results. First, the negative association between maturity and volatility of asset dynamics in a pooled OLS equation is insignificant, moreover the fixed effects regression results produce an opposite sign. Second, the maturity and leverage are negatively associated in both regressions, as we predicted. Third, we confirm that the relation between asset volatility and leverage is inversely related in base regression as well as ones with fixed effects. Lastly, the issuance costs, proxied by gross spread, have a positive association with debt maturity though this effect gets weaker in fixed effects regressions.

Difference method In a maturity equation, our empirical predictions are reassured; a firm with higher volatility of earnings tends to issue shorter-term bonds though its statistical power is insignificant. Second, a firm with shorter-term bonds tends to increase debt financing. Third, higher issuance costs counter-balance the financial flexibility by letting a firm start to issue longer maturity bonds. Among control variables, size, tangibility and cash holding have same signs with results from a pooled OLS. On the other hand, an increase in strong growth opportunity, measured as Market-to-Book ratio, has a different sign. It is negatively associated with debt maturity which supports the extant literature; short-term debt mitigates agency problems (Myers, 1977; Barclay, Smith, and Watts, 1995; Barclay, Marx, and Smith, 2003)

In the leverage equation results presented in Table 1.4, a firm's leverage is ex-

Table 1.3: Results from Pooled OLS Regressions

This table presents the pooled OLS regression results for two equations separately. Panel (a) reports estimation result for the maturity equation results (1.1), and panel (b) for the leverage equation (1.2). Numbers in the parenthesis are the *t*-statistics.

(a) Maturity equation

Dependent Variable:	Maturity	
	(i)	(ii)
Volatility	-1.00 (-0.61)	3.47 (1.73)*
Leverage	-2.66(-4.42)***	-1.99 (-2.69)***
Profitability	-3.48 (-1.60)	-4.57 (-2.04)**
Market-to-Book	0.13 (0.57)	0.60 (2.48)**
Tangibility	-0.73 (-1.70)*	1.00 (1.38)
Size	-0.66 (-9.33)***	-0.49 (-6.04)***
Cash holding	3.11 (2.47)**	3.93 (3.13)***
Gross Spread	0.09 (4.30)***	0.07 (3.52)***
Year Fixed	No	Yes
Industry Fixed	No	Yes
R Squared	0.10	0.29
Obs	1504	1504

(b) Leverage equation

Dependent Variable:	Leverage	
	(i)	(ii)
Volatility	-0.37 (-5.59) ***	-0.62 (-8.83)***
Maturity	-0.003 (-3.56) ***	-0.003 (-2.69)***
Profitability	-0.60 (-7.51) ***	-0.68 (-8.69)***
Market-to-Book	-0.12 (-14.3)***	-0.09 (-11.3)***
Tangibility	-0.12 (-7.38) ***	-0.07 (-2.82)***
Size	-0.04 (-14.2) ***	-0.04 (-13.1) ***
Cash holding	0.32 (6.90)***	0.32 (7.14) ***
Gross Spread	0.001 (1.36)	0.001 (1.89)*
Year Fixed	No	Yes
Industry Fixed	No	Yes
R Squared	0.60	0.64
Obs	1504	1504

plained by asset volatility, maturity and issuance costs with a statistical and economical significance. A firm with greater asset volatility, higher profitability, stronger growth opportunities, or higher tangibility tends to lever itself down, while a firm with higher cash holdings is likely to lever itself up.

Two-Stage Regression Our findings from a Pooled OLS regression and difference-in-difference method are mixed. The negative relation between volatility and maturity is statistically weak. Also, those results differ from with or without fixed effects in both a Pooled OLS and difference-in-difference regression. Corporate finance literature has been recognized the simultaneous decision among firm's financial policy. Advanced econometric tools are much used for resolving the endogeneity. In order to tackle this problem, we estimate a two-stage least squares (2SLS) system of equations in which the standard errors of the coefficients are adjusted for the clustering of observations at the firm level.

Table 1.5 provides 2SLS regression results;panel (a) presents the regression from debt maturity whereas panel (b) leverage equation. First, a firm with high uncertainty on earnings is likely to shorten the maturity of debt. As the uncertainty becomes higher, a firm acknowledges the flexible benefits from short-term financing. Second, a firm with shorter maturity of debt tends to lever up. A firm with short-term debt financing enjoys its flexibility to manage its leverage, which helps a firm accommodate more debt. Third, a firm with higher issuance costs tends to issue longer debt maturity since expensive issuance costs outweigh the flexibility benefits. This is consistent with the extant literature on a underwriter compensation and issue costs (Gande et al., 1997; Melnik and Plaut, 1996). Moreover, the results from leverage regressions in the lower panel support the negative relationship between maturity, leverage, and asset volatility. Our 2SLS regression results support our main empirical implications; a firm with shorter debt maturity optimally increases its debt, thereby making full use of the available financial flexibility, while a firm with higher volatility asset dynamics optimally tends to lever itself down, thereby reducing its financial distress.

We also look at whether our findings from other variables are consistent with the extant literature. In a maturity equation, size is negatively related with bond maturity; bigger firms tend to issue short-term bonds. Guedes and Opler (1996) and Johnson (2003) suggest firm size as proxy for credit quality. They elaborate that

Table 1.4: Regression using Difference method

This table presents the regression results based on a difference method. Panel (a) reports estimation result for the maturity equation results (1.3), and panel (b) for the leverage equation (1.4). Numbers in the parenthesis are the *t*-statistics.

(a) Maturity difference equation

Dependent Variable:	△ Maturity	
	(i)	(ii)
△Asset Volatility	-0.55 (-0.53)	-1.15(-1.05)
△Leverage	-1.58 (-1.91)*	-1.23 (-1.43)
△Profitability	3.57 (1.79)*	3.40 (1.67)*
△Market-to-Book	-0.58 (-2.55)**	-0.48 (-2.08)**
△Tangibility	0.31 (0.40)	0.62 (0.79)
△Size	-0.67 (-5.42) ***	-0.72 (-5.63)***
△Cash holding	1.34 (1.13)	1.10 (0.93)
△Gross Spread	0.22 (7.68) ***	0.22 (7.64)***
Year Fixed	No	Yes
Industry Fixed	No	Yes
R Squared	0.10	0.17
Obs	1504	1504

(b) Leverage difference equation

Dependent Variable:	△Leverage	
	(i)	(ii)
△Asset Volatility	-0.10 (-2.76) ***	-0.11 (-3.02) ***
△Maturity	-0.002 (-1.91) **	-0.001(-1.43)
△Profitability	-0.70 (-10.9)***	-0.72 (-11.2) ***
△Market-to-Book	-0.09 (-12.4)***	-0.08 (-11.6)***
△Tangibility	-0.04 (-1.41) ***	-0.03 (-1.26)
△Size	-0.05 (-13.7) ***	-0.05 (-13.6) ***
△Cash holding	0.11 (2.70)***	0.11 (2.87)***
△Gross Spread	0.003 (2.70) ***	0.002 (2.31)**
Year Fixed	No	Yes
Industry Fixed	No	Yes
R Squared	0.60	0.58
Obs	1504	1504

Table 1.5: Two Stage Regression

This table presents the results from the two-stage regression of maturity and leverage on the explanatory variables as specified in the system of simultaneous equations (1.5). Numbers in the parenthesis are the *t*-statistics.

Dependent Variable:	Maturity	
	(I) First	(II) Second
Leverage(predicted)		-2.44 (-3.56)**
Volatility	-0.34 (-5.63)***	-3.52 (-1.98)**
Profitability	-0.60 (-7.98)***	-3.48 (-1.60)
Market-to-Book	-0.13 (-17.6)***	-0.73 (-1.70)*
Tangibility	-0.10 (-6.95)***	0.13 (0.57)
Size	-0.03 (-13.2)***	-0.66 (-9.33) ***
Cash holding	0.23 (5.41)***	3.11 (2.47) **
Gross spread	0.0002 (0.32)	0.09 (4.30) ***
Tax Credit dummy	0.03 (3.80)***	
Acquisition dummy	0.02 (2.45)**	
Industry Leverage	-0.28 (-16.3)***	
R Squared	0.58	0.10
F-test	172.5	15.87
Obs	1504	1504

(a) Maturity equation

Dependent Variable:	Leverage	
	(I) First	(II) Second
Maturity(predicted)		-0.003 (-3.56)***
Volatility	3.46 (2.36)**	-0.37 (-5.59)***
Profitability	-2.80 (-1.56)	-0.09 (-9.99)***
Market-to-Book	0.49 (2.79) ***	-0.12 (-14.3)***
Tangibility	0.19 (0.57)	-0.12 (-7.38)***
Size	-0.25 (-4.60)***	-0.04 (-14.2)***
Cash holding	1.69 (1.65)	0.32 (6.90)***
Gross Spread	0.05 (2.87)***	0.001 (1.36)
Industry Maturity	0.93 (28.6)***	
Term spread	0.01 (0.09)	
Z-score_dummy	-0.12 (-0.65)	
R Squared	0.41	0.50
F-test	86.97	149.91
Obs	1504	1504

(b) Leverage equation

higher credit quality firms are likely to issue both short and long-end of maturity, while firms with lower credit quality choose medium maturity. In a leverage equation, size has a negative coefficient. Our finding supports that of Childs, Mauer, and Ott (2005); a proxy of firm size as default risk, which is inversely related to the leverage ratio. Barclay, Marx, and Smith (2003); Johnson (2003) and MacKay (2003) among others find that larger firms tend to issue long-term debt with less debt in capital structure, which is consistent with our finding.

Our findings support the benefits of short-term debt in reducing agency problems; a growth opportunities, measured as Market-to-Book ratio, is negatively associated with debt maturity. The literature of debt maturity has been focused on agency problems; Jensen and Meckling (1976) point out that equity holders increase investment risk by asset substitution. Myers (1977); Barnea, Haugen, and Senbet (1980); Stohs and Mauer (1996) among others, suggest that short-term debt mitigates agency costs or under-investment problems. Our empirical finding is consistent with cash holding effects on maturity and leverage; the debt maturity gets longer as cash holdings increase. Cash is substituted to short-term debt as a mean of flexibility. We also see the relation between leverage and profitability as well as leverage and tangibility from leverage regression results. As a firm becomes more profitable, with higher proportion of tangible asset, and stronger growth opportunities, a firm also levers itself down. Hovakimian, Opler, and Titman (2001) suppose that firms with higher proportions of tangible assets are likely to increase debt financing, because such assets can be used as collateral.

We draw attention on the role of asset volatility on the financial policy; maturity and leverage. On one hand, flexibility benefits become more valuable to a firm with highly volatile assets, hence a firm with high volatility of asset tends to issue shorter-term debt. On the other hand, a firm with high volatility of assets may has high bankruptcy probabilities as well; asset volatility is inversely related to the leverage. Stohs and Mauer (1996); MacKay (2003); Johnson (2003) also find the negative relation between maturity and volatility. In contrast, Diamond (1992); Guedes and Opler (1996); Childs, Mauer, and Ott (2005) predict that the relation is non-linear; firms with low volatility tend to issue both short-end and long-end of maturity and firms with high volatility tend to issue debt with a middle-term maturity.

We utilize the coefficient estimates of the maturity equation to calculate the effect on mean maturity of a one-standard deviation increase in volatility in order to estimate the economic significance of the effect of volatility's influence on the debt maturity. A one-standard deviation increase in volatility shortens debt maturity by 2.5%, reducing bond maturity from its mean of 8.5 years to 8.3 years. The economic effect of volatility to maturity is rather smaller comparing with other estimates. We look at how economic effects of other estimates in a maturity equation; a one-standard deviation increase in leverage decreases debt maturity by 6%, reducing bond maturity from its mean of 8.5 years to 8 years. Size matters since a one-standard deviation increase in size(measured as log(total asset)) shortens debt maturity by 11%, reducing bond maturity from its mean of 8.5 years to 7.4 years. The effect of issuance costs on debt maturity is economically significant; a one-standard deviation increase in issuance costs (measured as gross spread) increases debt maturity by 6%, lengthening bond maturity from its mean of 8.5 years to 9.1 years. Next, we examine the economic effects of leverage equations. First, the effect of volatility to leverage is economically significant; a one-standard deviation increase in volatility decreases its leverage by 5%, lowering its leverage ratio from its mean of 0.47 to 0.45. Second, maturity also influences leverage reduction; a one-standard deviation increase in maturity reduces its leverage by 5%, cutting down its leverage ratio from its mean of 0.47 to 0.45. Size is an important factor for leverage too; a one-standard deviation increase in size(measured as log(total asset)) decreases its leverage by 14%, reducing its leverage ratio from its mean of 0.47 to 0.34. Lastly, the economic effect of cash holding to leverage is substantial as well; a one-standard deviation increase in cash holding increases its leverage by 16%, boosting its leverage ratio from its mean of 0.47 to 0.53.

1.4 Renegotiability: DealScan Sample

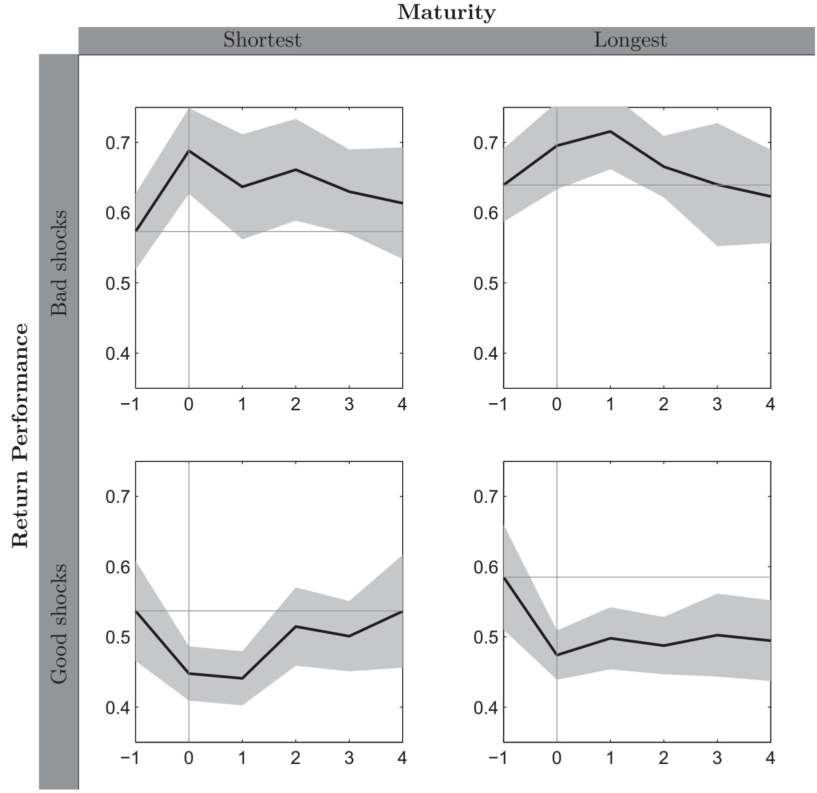
We investigate DealScan data using the maturity of bank loans as a proxy for debt maturity. Our analysis will illustrate a further evidence on whether different types of debt, for example, public debt vs. private debt, shows distinct implications on a firm's financial policy. Thomson-Reuters' LPC DealScan (DealScan), also known as Loan Pricing Corporation Deal Scan, provides reliable information on the global commercial loan market. DealScan database contains a comprehensive historical information on loan pricing, contracts details, terms and conditions. DealScan data are compiled from SEC filings and public documents (10Ks, 10Qs, 8Ks and registration statements), and loan syndicates as well as other internal sources. We again explore our empirical implications using bank loan sample. We proxy debt maturity as time-to-maturity of loan. We expect the interaction among maturity, leverage, and asset volatility in bank loan might differ from that of bonds. A bank loan has a higher possibility of renegotiation along the path of performance of firms. The bank can closely monitor a firm's performance and rearrange its interest rates, maturity, amount outstanding, and so on during its loan's lifetime. For example, Roberts and Sufi (2009) find that 90% of private credit contracts are renegotiated prior to their stated maturity.

Table 1.6 provides summary statistics of bank loan sample between 1987 through 2010. The final sample consists of 5196 loan observations. Some observations for other variables are missing. The maturity of bank loans is estimated as 2.56 years. The average amount of bank loans is 150 million dollars(median) and 299 million dollars(mean) which indicates the tail distribution of bank loan is positively skewed. AllInUndrawn spread measures the amount a borrower pays for each dollar available under a commitment. It adds the commitment and annual fee. Sales is the financial amount by which the company's revenue is measured.

1.4.1 Leverage Dynamics

We examined how a firm can adjust downward(upward) when it is hit by negative(positive) shocks. We also compare firms with debts of shorter maturity to the equivalents with debts of longer maturity. Using DealScan sample, we look at whether private debt maturity reacts to performance shocks in a different manner comparing to public debt. We keep a same procedure in sorting firms into 25 bins, first by performance and second by maturity following Section 3.

Figure 1.3 illustrates the dynamic leverage reduction from $t-1$ through $t+4$ with the firms hit by the performance shock in $t = 0$. Upper panel of Figure 1.3 shows the leverage dynamics when a firm was hit by a negative performance shock. The average leverage has mechanically risen between $t = -1$ and $t = 0$, since the value of equity decreases by a negative shock. The leverage dynamics of bank loan sample differ from cooperate bond sample; both groups with shorter-term and longer-term



Note: The figure shows the dynamics of leverage for firms different in their return performance at $t = 0$ and maturity structure of bank loans. The thick solid line traces the mean value of leverage ratio for each group. The shaded area represents 95% confidence interval. The light-grayed horizontal line indicates the initial ratio of leverage.

Figure 1.3: Leverage Dynamics: Case of Renegotiable Debt (data: DealScan Bank Loans)

Table 1.6: Summary Statistics of DealScan Sample

This table provides summary statistics of bank loans between 1987 through 20010. The final sample consists of 5196 loan observations. Some observations for other variables are missing. The maturity of bank loans is measured as amount weighted maturity and the mean of maturity is 2.56 years. The average amount of bank loans is 150 million dollars(median) and 299 million dollars(mean), which indicates the tail distribution of bank loan is positively skewed. AllInUndrawn measures the amount a borrower pays for each dollar available under a commitment. It adds the commitment and annual fee. Commitment Fee measures the amount a borrower pays for each dollar available under a commitment. Sales At Close is the financial amount by which the company's sales revenue is measured as of the closing date of the agreement

Variables	Obs	Mean	Std	Min	Max
Loan Maturity	5548	2.56	1.74	0.00	10.0
AllInUnDrawn	4860	36.8	23.2	0.25	283.2
Loan Amt/Sales	3662	0.34	0.70	0.00	21.6
Loan Amt(Million)	5548	396.9	817.6	0.21	22,237.4
Sales(Million)	5042	4,334.3	45,776.2	-4,214.9	1,851,180.0

loan hit by negative shocks increase their leverage automatically at the first year. Group of firms with shorter-term loan start to decrease their leverage at $t = 1$ but recover it at $t = 2$, while firms with longer-term loan start to delever at $t = 2$ and keep delevering until $t = 4$.

Lower panel shows the average leverage dynamics due to positive performance shocks. Firms with the shortest maturity quickly raise their leverage after the positive shock, while firms with the longest maturity are slower to increase the leverage. All firms behave in a similar pattern; by increasing their leverage after a positive shock. The upward adjustments hit by positive shocks are observed in both public debt and private debt.

1.4.2 Cross-sectional Results

Simple Regression We test the four predictions following Section 4 and look at whether a firm adjusts its optimal financial policy differently when it is financed with bank loan too. As variables of interests, we proxy debt maturity as loan amount weighted time-to-maturity, issuance costs as all-in-undrawn spread and leverage as the fraction of total debt to sum of debt and market value of equity.

Table 1.7 provides the results from OLS regression. In each equation, column

Table 1.7: Results from Pooled OLS Regressions: DealScan Sample

This table presents the pooled OLS regression results for two equations separately. Panel (a) reports estimation result for the maturity equation results (1.1) and panel (b) for the leverage equation (1.2). In each equation, the first column (i) shows the results without fixed effects, and the second column (ii) with both year and industry fixed effects. Numbers in the parenthesis are the *t*-statistics.

Dependent Variable:	Loan Maturity	
	(i)	(ii)
Asset Volatility	1.10 (3.59) ***	0.19 (0.50)
Leverage	0.55 (3.40) ***	-0.05 (-0.24)
Profitability	0.50 (1.49)	0.71 (1.86)*
Market-to-Book	0.17 (4.00)*	0.03 (0.58)
Tangibility	-0.37 (-3.20) ***	-0.09 (-0.50)
Size	0.06 (2.70)***	0.10 (4.01) ***
Cash Holding	0.01 (0.11)	0.05 (0.69)
Loan amount/sales	0.08 (1.30)	0.09 (1.28)
Issuing costs	0.003 (2.33)**	0.005 (3.01) ***
Year Fixed	No	Yes
Industry Fixed	No	Yes
R squared	0.02	0.22
Obs	2942	2255

(a) Maturity equation

Dependent Variable:	Leverage	
	(i)	(ii)
Asset Volatility	-0.49 (-14.3)***	-0.69 (-17.5)***
Loan Maturity	0.01 (3.40)***	-0.001 (-0.24)
Profitability	-0.11 (-2.76)	-0.18 (-4.25)***
Market-to-Book	-0.10 (-21.9)***	-0.07 (-14.2)***
Tangibility	0.00 (-0.10)	0.02 (1.17)
Size	-0.03 (-12.8)***	-0.03 (-12.3) ***
Cash Holding	0.01 (1.67)*	0.00 (-0.14)
Loan amount/Sales	0.03 (4.92)***	0.01 (1.63)
Issuing costs	0.001 (6.50)***	0.001 (6.99)***
Year Fixed	No	Yes
Industry Fixed	No	Yes
R squared	0.35	0.52
Obs	2932	2255

(b) Leverage equation

(i) presents the OLS regression results without any fixed effects, while column (ii) gives OLS results with year and industry fixed effects. The main dependent variable is loan maturity in a maturity equation and market leverage in a leverage equation, respectively. We focus on leverage ratio, maturity, asset volatility, and issuance costs as independent variables of interests. Other control variables are firm's profitability, tangibility, Market-to-Book ratio, size, loan amount scaled by sales, and cash holdings. We find that the relationship between financial policy and asset volatility contradicts our findings from FISD data; the higher the asset volatility, the longer the maturity of loans. The higher fraction of debt to total assets a firm has, the longer the maturity of loan it issues. The relation between asset volatility and leverage is consistent with our finding from FISD data; the higher the asset volatility, the lower the leverage. It seems that bank loan achieves the flexibility benefits not from its stated maturity but from its renegotiation or restructuring. Prior works also confirm that bank loan are frequently renegotiated (Diamond, 1992; Roberts and Sufi, 2009). Results from bank loan sample support our theoretical propositions; the trade-off between transaction costs and the flexibility feature of debt contracts can be offset by the renegotiation possibility.

Two-Stage Regression In this section, we analyze the joint determination of debt maturity and leverage using DealScan data. Table 1.8 provides the 2SLS regression results with instrumental variables. Following Section 4, we used industry maturity, term spread, and acquisition dummy as instruments in the maturity equation and Altman's Z Score dummy, tax credit dummy, and industry average leverage as instrument variables in the leverage equation. The upper panel reports the results of maturity equation while the lower panel presents ones of leverage equation. We find that the two-stage regression results are consistent with our findings from a base regression (see Table 1.7). Firms having debts with long-term loan lever up, while firms having high uncertainty on asset dynamics tend to finance with long-term loan. These results dispute our findings from FISD sample regressions. Next, we find that a firm with high volatility of asset dynamics reduces its leverage, thereby managing its financial distress, which is consistent with FISD sample.

We also utilize the coefficient estimates of the maturity equation to calculate the effect on mean maturity of a one-standard deviation increase in volatility in order

Table 1.8: Two Stage Regression: DealScan Sample

This table provides the results when DealScan sample is brought into two-stage regression with instrumental variables. Panel (a) reports the results when having loan maturity as dependent variable, and panel (b) reports the results when having leverage as dependent variable.

Dependent Variable:	Loan Maturity	
	(I) First	(II) Second
Leverage(Predicted value)		0.55(3.40)***
Volatility	-0.45(-14.1)***	1.10 (3.59) ***
Profitability	-0.11 (-3.06)***	0.50 (1.49)
Market-to-Book	-0.10 (-23.7)***	0.17 (4.00)***
Tangibility	0.02 (1.44)	-0.37 (-3.20)***
Size	-0.03 (-13.1)***	0.06 (2.70)***
Cash Holding	0.01 (1.35)	0.01 (0.11)
Loan amount/Sales	0.03 (4.56)***	0.08 (1.30)
Issuance costs	0.001 (5.77)***	0.003 (2.33)**
Industry Leverage	-0.28 (-20.1)***	
Tax Credit Dummy	0.02 (2.43)**	
Acquisition Dummy	-0.02 (-4.01)***	
R squared	0.02	0.22
Obs	2942	2255

(a) Maturity equation

Dependent Variable:	Leverage	
	(I) First	(II) Second
Maturity(Predicted value)		0.05 (1.96)**
Volatility	0.21 (0.76)	-0.49 (-12.9)***
Profitability	0.96 (2.93)***	-0.10 (-2.22) **
Market-to-Book	0.02 (0.46)	-0.08 (-17.4)***
Tangibility	-0.07 (-0.58)	0.01 (0.94)
Size	0.05 (2.47) **	-0.03 (-10.9)***
Cash Holding	-0.02 (-0.38)	0.01 (1.48)
Loan amount/Sales	0.05 (0.91)	0.02 (2.81)
Issuance costs	0.003(2.18)**	0.001 (6.14)***
Industry maturity	0.97 (32.1)***	
Term Spread	0.00 (-0.13)	
Z-Score Dummy	-0.04 (-0.65)	
R Squared	0.37	0.37
Obs	2255	2255

(b) Leverage equation

to estimate the economic significance of the effect of volatility's influence on bank loan maturity. A one-standard deviation increase in volatility lengthens bank loan maturity by 3%, increasing bank loan maturity from its mean of 2.6 years to 2.7 years. The economic effect of volatility to loan maturity is small since we entangle the endogeneity between leverage and maturity using two stage regression methods with instruments. The economic effect of leverage to loan maturity is significant; a one-standard deviation increase in leverage increases loan maturity by 5%, lengthening loan maturity from its mean of 2.6 years to 2.72 years. We also see the economic effects of control variables. Size's economic effect gets much reduced comparing with bond issuance sample; a one-standard deviation increase in size(measured as log(total asset)) lengthens bank loan maturity by 4%, increasing loan maturity from its mean of 2.6 years to 2.7 years. The economic effect of issuing costs becomes weaker too; a one-standard deviation increase in issuance costs (measured as AllInUndrawn) increases debt maturity by 3%, lengthening bond maturity from its mean of 2.6 years to 2.7 years. Next, we look at the economic effects of leverage equation. First, a one-standard deviation increase in volatility decreases its leverage by 6%, reducing its leverage ratio from its mean of 0.47 to 0.44. This result is consistent with bond issuance sample. The economic effect of loan maturity to leverage is substantially big in loan sample; a one-standard deviation increase in maturity increases its leverage by 19%, lengthening its leverage ratio from its mean of 0.47 to 0.56. Finally, size has a strong economic effect to leverage too; a one-standard deviation increase in size(measured as log(total asset)) decreases its leverage by 10%, reducing its leverage ratio from its mean of 0.47 to 0.42.

We analyze the financial policy in a dynamic capital structure using DealScan sample in this section and compare the results with the FISD sample in section 3. We find that an endogenous decision between maturity and capital structure in DealScan sample differs from that in FISD sample. The frequent renegotiation of loan contracts lets its behavior differ from the financial policy analysis with the FISD sample. Firms financed with bank loans can adjust their optimal leverage without counter-balancing the effects of the flexibility benefits of maturity and the transaction costs of new issuance. The flexibility benefits using bank loans comes from by means of renegotiation rather than maturity at issuance. Lastly, a firm with high asset volatility levers itself down; this result is very persistent with both FISD and DealScan sample. Thus, our empirical finding supports the classical trade-off theory, between tax benefits and financial distress. A firm, regardless of finance with private or public debt, manages its capital structure in order to reduce a firm's financial distress when the uncertainty of earnings becomes more volatile.

1.5 Exercisibility: Compustat Sample

We compare FISD sample measured maturity as corporate bond's time-to-maturity in Section 4 with DealScan sample using bank loan's maturity in Section 5. Now, we employ Compustat sample for robustness. Debt maturity from Compustat database is defined as an aggregated remaining time-to-maturity of long-term debt outstanding while we proxy maturity as time-to-maturity of bond at the time of issuance using a new bond issuance data from FISD database. Guedes and Opler (1996) suggest an incremental approach in estimating the joint decision of financial policy whereas Johnson (2003); Barclay, Marx, and Smith (2003) and others utilize an aggregated debt maturity. An incremental approach is more suitable when the financial policy quickly adjusts to faster moving state variables at the time of issuance. Whereas an aggregate one is effective, when its decision on financial policy is affected by slow moving state variables. In prior works using Compustat data, debt maturity is measured as a fraction of a firm's long-term debt maturing in less than or equal to 2 years, 3 years, 4 years and 5 years (Barclay, Smith, and Watts, 1995; Johnson, 2003, Billett, King, and Mauer, 2007). Harford, Klasa, and Maxwell (2014) use similar measures but excludes debt due within a year because a debt matured less than a year is mainly used to finance a firm's short-term liquidity needs.

We exclude bonds with any optional features in Section 4 since those features makes maturity of bonds not fixed. For example, a callable bond with 10 years of maturity at the time of issuance can be called after half of its expected maturity. Compustat database has a basket of bonds with optional features, whose are not informed. Therefore, we expect Compustat sample has much noise in defining maturity of debts since it includes all optional features from bonds and summing up all existing debts a firm has issued.

Summary Statistics Table 1.9 presents summary statistics for 25,182 firm-year observations over 1987 to 2010. We define a debt maturity as a fraction of total long-

Table 1.9: Summary Statistics for Compustat Sample

This table presents summary statistics for debt due in next three years(DD2+DD3) excluding DD1, scaled by total long-term debt(DLTT). We also report similar measures such as DD1/DLTT (a fraction of long-term debt due in next year) and DD5/DLTT(a fraction of long-term debt due in next 5 years excluding DD1).

Variable	No.Obs	Mean	Median	Std. Dev	Min	Max
DD1/DLTT	25182	0.29	0.05	1.30	0.00	8.58
DD3/DLTT	21775	0.27	0.18	0.28	0.00	1.00
DD5/DLTT	21294	0.51	0.47	0.32	0.00	1.06
Book Lev	27823	0.42	0.45	0.34	0.00	0.98
Market Lev	27823	0.54	0.52	0.21	0.10	0.98
Size	27823	6.54	6.66	2.00	0.00	0.91
Cash Holding	27720	0.16	0.04	0.28	0.00	3.85
Profitability	26236	0.09	0.10	0.10	-0.41	0.36
Market-to-Book	27823	1.05	0.88	0.63	0.19	4.72
Tangibility	26254	0.37	0.33	0.28	0.00	0.91
Asset Volatility	19690	0.19	0.15	0.12	0.00	0.82
Z-score	20820	1.98	1.91	1.71	-5.42	7.91

term debt due in next three years excluding maturing debt within a year (DD2+DD3-DD1), scaled by total long-term debt(DLTT) following Harford, Klasa, and Maxwell (2014). We also use similar measures such as a fraction of long-term debt due in next year (DD1/DLTT) and a fraction of long-term debt due in the next 5 years excluding maturing debt within a year[(DD5-DD1)/DLTT] for robustness. All other variables are defined in Table 1.1.

1.5.1 Leverage Dynamics

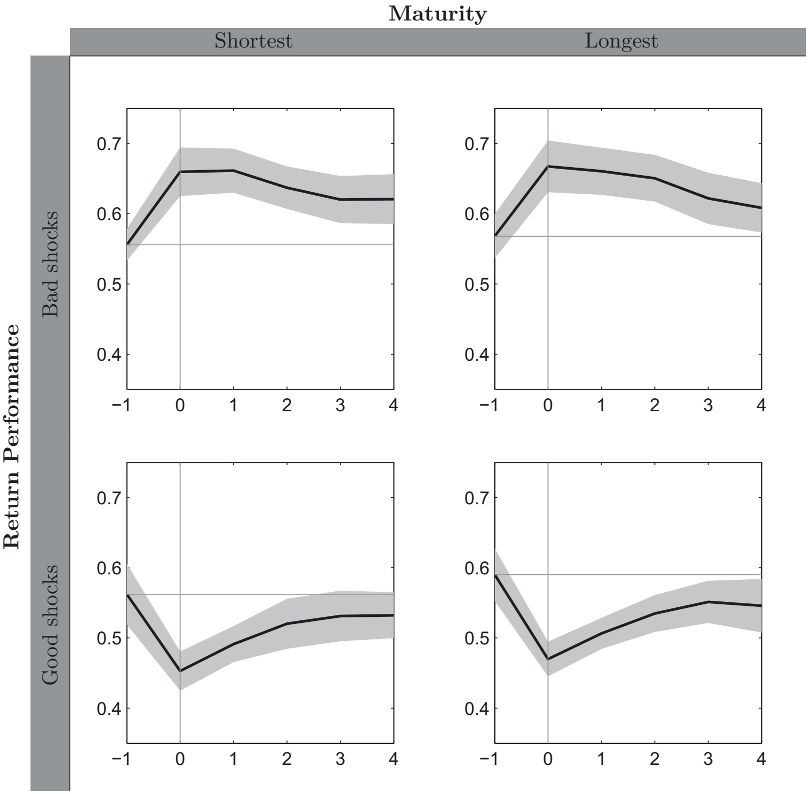
We analyze the leverage dynamics using Compustat data whether short-term financing gives a firm its flexibility towards an rapid readjustment when a firm was hit by negative performance shocks. Using the same methods applied earlier, firms are first sorted by quin-tiles of performance in each year and sorted by quin-tiles of maturity from shortest to longest over 1987 to 2010. Upper panel of Figure 1.4 illustrates the dynamic leverage from $t-1$ through $t+4$ with the bad shock in $t=0$. With a bad shock at $t=0$, the leverage ratio mechanically rises in both the shortest and the longest maturity group. On one hand, a firm historically issued the short-term debt delever itself between $t=1$ and $t=2$ while a firm historically issued the long-term debt keeps raising its leverage until $t = 2$. The former lets some debts matured when it was hit by a negative shock whereas the latter cannot shake off some debts even with higher bankruptcy probability, thereby increasing its financial distress.

Lower panel of Figure 1.4 illustrates the leverage dynamics from $t - 1$ through $t + 4$ for the firms in a group with the highest performance shock in $t = 0$. With the positive shock at $t = 0$, the leverage ratio mechanically falls down in both the short maturity group and the longer maturity one. Both firms start to increase their debt level from $t = 1$, whose tendency continues over the observed years.

1.5.2 Cross-sectional Results

Simple Regression In our maturity equation, we use debt maturity defined as 1-DD3/DLTT as the main dependent variable, where DD3/DLTT is a fraction of remaining maturity greater than 3 years. Our independent variables of interest are the leverage ratio and asset volatility. Unfortunately, it is difficult to proxy a variable measuring cost of issuance from Compustat data. We investigate whether the alternative proxy of debt maturity affects our empirical analysis. Table 1.10 presents regression results from the maturity of debt (leverage) is regressed on the determinants of debt maturity (leverage) as well as on the control variables with year, industry and firm fixed effects. The regression coefficients on leverage and asset volatility are statistically different from zero with the negative signs, while the coefficient on asset volatility with year, industry, and firm fixed effects has an opposite sign. This indicates that, controlling for potential changes in year, industry, and firm characteristics over time, asset volatility does not affect in a persistent manner in explaining the debt maturity. The lower panel reports that the signs of coefficients on the leverage model are very persistent and statistically significant in both a pooled OLS and fixed effects regression.

Two Stage Regression Table 1.11 provides regression results for the two-stage regression with instrumental variables. The upper panel shows that the coefficients on leverage and volatility are statistically significant and consistent with respect to the base regression results. The fraction of debt matured in within 3 years excluding less than a year, increases along with a firm's leverage and asset volatility. The coefficient on asset volatility is statistically significant while the coefficient on leverage not. The



Note: The figure shows the dynamics of leverage for firms different in their return performance at $t = 0$ and maturity structure of cumulative debt. The thick solid line traces the mean value of leverage ratio for each group. The shaded area represents 95% confidence interval. The light-grayed horizontal line indicates the initial ratio of leverage.

Figure 1.4: Leverage Dynamics: Case of Cumulative Debt (data: Compustat)

Table 1.10: Results from Pooled OLS Regressions: Compustat Sample

This table presents the pooled OLS regression results for two equations separately. Panel (a) reports estimation result for the maturity equation results (1.1) and panel (b) for the leverage equation (1.2). In each equation, the first column (i) shows the results without fixed effects, the second column (ii) with year and industry fixed effects, and the third column (iii) with firm, year, and industry fixed effects. Numbers in the parenthesis are the *t*-statistics.

Dependent Variable:		1-DD3/DLTT	
	(i)	(ii)	(iii)
Leverage	-0.22(-9.02) ***	0.03 (2.02)**	0.04 (2.27)**
Asset volatility	-.058(-0.89)	0.21 (8.15) ***	-0.06 (-1.97) ***
Profitability	-0.28(-3.60)***	-0.07 (-2.46)**	0.004 (0.11)
Market-to-Book	0.004(0.48)	0.02 (3.76)***	0.02 (3.08)***
Tangibility	0.13(7.94) ***	-0.08 (-6.30) ***	-0.05(-2.11)**
Size	-0.02(-6.05) ***	-0.04 (-25.7) ***	-0.06 (-13.6) ***
Cash holding	0.02(0.43)	-0.04 (-6.55) ***	-0.04 (-4.87) ***
Year Fixed	No	Yes	Yes
Industry Fixed	No	Yes	Yes
Firm Fixed	No	No	Yes
R squared	0.15	0.22	0.58
Obs	20300	20300	20300

(a) Maturity equation

Dependent Variable:		Leverage	
	(i)	(ii)	(iii)
Maturity	0.04 (8.55)***	0.01 (2.02) **	0.003 (0.67)
Asset volatility	-0.40 (-30.6)***	-0.49 (-36.8) ***	-0.38 (-27.4) ***
Stock Return	-0.06 (-24.7) ***	-0.05 (-21.3)***	-0.05 (-23.6)***
Profitability	-0.22 (-14.2) ***	-0.31 (-21.4) ***	-0.36 (-21.2) ***
Market-to-Book	-0.14 (-69.3) **	-0.14 (-67.2)***	-0.13 (-48.4)***
Tangibility	-0.07 (-14.6)***	-0.01 (-1.20)	0.05 (4.07)***
Size	-0.02 (-31.9) ***	-0.06 (-27.5) ***	-0.02 (-10.2)***
Cash holding	0.06 (20.7) ***	0.04 (14.1) ***	-0.01 (-2.02)**
Year Fixed	No	Yes	Yes
Industry Fixed	No	Yes	Yes
Firm Fixed	No	No	Yes
R squared	0.45	0.60	0.85
Obs	20300	20300	20300

(b) Leverage equation

Table 1.11: Two Stage Regression: Compustat Sample

This table presents the results when Compustat sample is brought into the two-stage regression of maturity and leverage on the explanatory variables as specified in the system of simultaneous equations (1.5). Numbers in the parenthesis are the *t*-statistics.

Dependent Variable:	1-DD3/DLTT	
	(I) First	(II) Second
Leverage(Predicted)		-0.06(-0.75)
Volatility	-0.50 (-42.5)***	-0.21(-4.80)***
Profitability	-0.33 (-26.7)***	0.07 (1.74)*
Market-to-Book	-0.14 (-80.2)***	-0.02(-1.64)
Tangibility	0.001 (0.22)	0.08(6.25)***
Size	-0.02 (-32.2)***	0.04(16.5)***
Cash holding	0.04 (15.5)***	0.04(6.07)***
Tax Credit Dummy	0.05 (18.9)***	
Acquisition Dummy	-0.008 (-3.26)***	
Industry Leverage	-0.18 (-17.3)***	
Year Fixed	Yes	Yes
Industry Fixed	Yes	Yes
R Squared	0.53	0.22
F-test	201.8	39.6
Obs	18578	14528

(a) Maturity equation

Dependent Variable:	Leverage	
	(I) First	(II) Second
Maturity(Predicted)		0.05 (2.95)***
Volatility	-0.17 (-7.11)***	-0.53 (-40.1)***
Profitability	0.13 (4.12)***	-0.36 (-27.2)***
Market-to-Book	-0.02 (-4.48)***	-0.13 (-67.3)***
Tangibility	0.06 (4.12)***	-0.002 (-0.31)
Size	0.04 (27.7)***	-0.038 (-34.6)***
Cash holding	0.06 (8.60)***	0.01 (3.16)***
Industry Maturity	-0.92 (-34.5)***	
Term spread	-0.007(0.00)	
Z Score Dummy	-0.004(-2.14)**	
Year Fixed	Yes	Yes
Industry Fixed	Yes	Yes
R Squared	0.30	0.52
F-test	52.48	157.66
Obs	12252	14286

(b) Leverage equation

leverage equation results in the the lower panel show that the higher short-term debt fractions in total long-term debt, the higher leverage ratio. As the asset dynamics of firm become more volatile, a firm levers itself down in order to reduce the probability of financial distress. This is very persistent among different samples, supporting a trade-off theory of optimal leverage decision.

With the same definition of debt maturity and leverage specifications using Compustat data, Johnson (2003) elaborates how short-term debt affects on the leverage decision. On one hand, short-term debt attenuates under-investment by reducing agency costs and makes a firm engage more debt. On the other hand, a firm, with a higher proportion of short-term debt, reduces debt outstanding to relieve liquidity risks. Hence, the net effects of short-term debt on the leverage depend on the counter-balancing forces of attenuation effects and liquidity risks. Our empirical finding are contrasting with Johnson (2003); the net effects of the proportion of short-term debt to total debt is positive on the explanation on the leverage as well as the flexibility benefits plus the attenuation of under-investment problems act against the liquidity risk, hence the net effect of short-term debt on leverage is positive. The higher proportion of short-term to total debt increases the leverage. Childs, Mauer, and Ott (2005) also find that a firm chooses short-term debt in order to take financial flexibility; short-term debt reduces the agency costs of under- and over-investment. Nevertheless, they argue that the effect of short-term debt on leverage may not be positively related, since a firm's debt level also depends on the type of growth option.

1.6 Conclusions

We examine how firms determine their maturity and leverage. We depart from earlier studies by giving the credit to the fact that maturity is not the only way the financial flexibility can embody in. We construct three samples accordingly; sample having flexibility in debt maturity, sample having flexibility in debt renegotiability, and sample having flexibility in debt exercisibility. While controlling these features, our study discovers a clear-cut relationship between maturity, leverage, and volatility of business environment.

Our new findings include that (1) firms with debt of shorter maturity are much faster in re-balancing their leverage ratios; (2) firms facing more volatile earnings tend to issue debt with shorter maturity; (3) firms with shorter maturity debt tend to lever themselves up to higher leverage; (4) firms facing more volatile earnings tend to make lower leverage; (5) firms with lower issuance costs tend to issue debt with shorter maturity.

With these findings, this paper contributes to the existing literature in several aspects. First, this paper confirms the traditional wisdom established in the literature with respect to the two theoretical pillars of the dynamic capital structure models. Second, it provides new evidence that where the financial flexibility is inherently contained in debt maturity, debt of shorter maturity benefits a firm in respect of financial flexibility under volatile business environments, while at the same time the financial flexibility contributes to a firm's debt capacity. Third, this paper highlights the importance of discerning flexibility in various forms: A failure to discern and control flexibility content out of debt types and aggregation methods can potentially mislead one in examining corporate maturity policy. This helps reconcile a body of previous empirical studies seemingly contradicting one another.

Chapter 2

Sharing Downside Risks: Contingent Coupon Bonds

We propose and solve a model of optimal capital structure in which the growth rate and volatility of the earnings shift between different states. We show that a firm can enter coupon payment contracts on contingency; paying higher coupon in Good state and lower in Bad state. We show that this type of security allows for an effective risk-sharing between a firm and investors. Our results suggest that contingent coupon bonds can help a firm be resilient hit by systemic downside risks.

2.1 Introduction

Contingent Capital Bonds(CoCos) are proposed to reinforce the resilience of financial system(Barucci and Del Viva (2010); Calomiris and Herring (2011); Flannery (2014); Albul, Jaffee, and Tchistyi (2015)). In times of systemic distress a bank can not raise an additional equity capital, CoCos can provide it. Yet, CoCos might distort bank's ex ante incentives; both asset substitution and debt overhang(Albul, Jaffee, and Tchistyi (2015)). As documented by Avdjiev et al. (2015), CoCos provide capital buffer to banks while the effects on reducing risk-taking incentives is rather weak. This paper analyzes the effect of issuing bonds with a state-contingent coupon; which has a similar function with CoCos but is more flexible and weakens stakeholders' irrational incentives.

We start by adapting an investment decision model under uncertainty(Dixit and Pindyck (1994); Hassett and Metcalf (1999)). The literature looks for an investment timing when the growth rate and the volatility of state variables follow a stochastic process whereas we focus on capital structure decision following structural model in corporate finance. Brennan and Schwartz (1978); Leland (1994) and others consider debt and equity as contingent claims of firm value, thus they model and solve the optimal coupon rate of debt, once a trade-off between bankruptcy costs and tax benefits is perfectly balanced. We solve the model of capital structure and find the optimal decision of trade-off between tax benefits and bankruptcy costs when a firm's earning process shifts between Good and Bad regimes.

We show that the optimal decision under regime-switching produces a bond with procyclical contingent coupon rates; this pays out lower rates of coupon in Bad state while it compensates investors with higher rate in Good state. This feature makes our proposed security as a risk-sharing security for verifiable but excusable economic events. Our numerical analysis provides the benefits from issuing state-contingent coupon bonds; a firm is benefited from tax shields as well it reduces the bankruptcy probability in bad times by relieving liquidity shortage.

Our paper contributes several strands of literature. First, structural model has provided a theoretical background on issuing contingent capital (CoCos). In particular, after the recent 2007-2009 financial crisis, the literature on CoCos shows that bank issuing contingent capital can enhance its asset value as well as reduce the bankruptcy thresholds(Barucci and Del Viva (2010); Glasserman and Nouri (2010); Pennacchi (2010); Albul, Jaffee, and Tchistyi (2015)). . Moreover, it persuades regulators CoCos can be used as a kind of tools to discipline financial intermediaries. Following a classical model of optimal capital structure (Leland (1994); Leland and Toft (1996)), our model allows regime-switches on macroeconomic conditions, thus a firm optimally chooses to issue state-contingent coupon bonds. We provide numerical solutions to show that this hybrid bond can increase firm value and reduce the chance of costly bankruptcy by paying out pro-cyclical interests. The state-contingent coupon rate leads the security to resemble performance sensitive debt obligations whose coupon payments tied to a performance of issuer(Lando and Mortensen (2005),Manso, Strulovici, and Tchistyi (2010)), but in an opposite direction. The first difference is the conventional performance sensitive debt has a risk-compensating feature. Otherwise, the holder of a state-contingent coupon bonds shares the risks with the issuer. Second, the coupon rate of performance sensitive debt is determined by issuer's performance, which is a private information. In contrast, our suggested state-contingent coupon rate is adjusted to the public information triggered by systemic risks. Nonetheless there are few issuance of risk sharing bonds today, whereas Drelichman and Voth (2015) document that contingent sovereign debts enhance welfare benefits for monarchs as well as bankers in specified as well as non-contractual types of contingencies, using archival data.

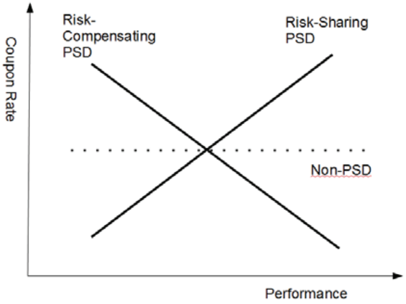
We propose and solve a model of optimal capital structure under a regime-switching framework and introduce a new form of hybrid capital as an outcome in this model. This type of security can alleviate firms' liquidity problem in times of high systemic risks. This security has varying coupon rates depending on the state of economy; a firm could lower coupon rates for currently due-interest payments if the issuer suffers large losses from existing investments due to recessionary shocks. By paying less interests to bondholders in times of low(or negative) cash flow, a firm can resolve the liquidity shortage and furthermore mitigate the downward liquidity spirals among other inter-connected firms in contracted credit market(Brunnermeier and Pedersen (2009)).

Whereas a state-contingent coupon bond shares its characteristics with traditional contingent convertible bonds (CoCos) in several ways. Furthermore, they can relieve CoCo's significant problems. First, it can resolve the irreversibility or the rigidity of CoCos. Once the trigger activated, CoCos convert to equity. However, it is very difficult to reverse from equity to original bonds even if the trigger has nullified sooner or later. A state-contingent coupon bond has a flexibility of rebalacing coupon rate back and forth as systemic risks fluctuate over the financial cycle. For example, the bondholders are paid by lower rates on a predetermined coupon paying date(i.e., semi-anuual or annual basis) when its performance hindered by systemic risks. Later, the contingent coupon rate can be readjusted if the triggers are invalidated before the next payment date. Second, it can reduce equity-holder's asset substitution incentives. With CoCos in its debt liability, equity-holders prefer to take a risky project, resulting in conversion of CoCos to equity. Nevertheless, a state-contingent coupon bond cannot eliminate asset substitution motives completely, in this case, equity-holders would consider the benefits and losses from sharing risks or gambling for a resurrection.

2.2 Related work

This study is in line with an extant literature studying the optimal capital structure. Modigliani and Miller (1958)'s capital structure irrelevance proposition introduces capital structure theory in corporate finance. Assuming no market frictions, the value of the firm is irrelevant from sources of financing. Followed by Miller (1977), taxes make an important role of optimal capital structure theory due to tax shields from debt financing. However, there is a trade-off; the more debt, the higher the cost of financial distress, leading to an optimal level of debt to equity ratio. Brennan and Schwartz (1978) contribute the theory by providing a quantitative analysis of optimal leverage when an equity-financed firm's value follows a diffusion process. Leland (1994) extends Brennan and Schwartz (1978) and derives the closed form solutions for the value of debt and the optimal capital structure.

This paper pursues to enrich to the literature on the optimal capital structure of a company, issuing contingent capital. Albul, Jaffee, and Tchistyi (2015) develop a closed form solution for CoCos adopting the model by Leland (1994) and Leland (1994). Barucci and Del Viva (2010) also study the optimal capital structure of a company issuing callable contingent capital. They show that this type of hybrid security reduces the spread of straight debt and expected bankruptcy costs but has a high spread, which is costly. Their findings are inconclusive since the firm with sufficiently small amount of CoCos actually increase both the value of firm and the equity-holder's welfare due to tax benefits from CoCos. However, the firm would not issue CoCos due to debt overhang problem in case of the leveraged firm assuming total amount of debt is fixed. Our study differs from Albul, Jaffee, and Tchistyi (2015) and Barucci and Del Viva (2010) since our model asset dynamics includes non-stationary components. The systemic risks or macroeconomic risks possess down a firm's earning process, furthermore might exacerbate its uncertainty too. Our model illustrate how a firm reacts to abrupt changes of state of economy and manages its



Note: This figure illustrates the relation between performance measure and coupon rate. We define risk-compensating PSD if coupon rate is a non-increasing and not a constant function on the performance measure. On the other hand, we define risk sharing PSD if coupon rate is a non-decreasing and not a constant function on the performance measure. Lastly, if coupon rate is a constant function on the performance measure then this is non-PSD.

Figure 2.1: The Type of Performance Sensitive Debt

optimal capital structure by issuing a hybrid security. The paper that is most closely related to Pennacchi, Vermaelen, and Wolff (2010); Pennacchi (2010). These authors also study an optimal capital structure when the dynamics of the state variable make jumps. One major difference between the two studies is that we allow a regime-switching of the growth rate and the volatility of state variables whereas they model the state variables follow a jump diffusion process. Consequently, we show that a firm optimally decides to pay state-contingent coupons in this framework. In their analysis, Pennacchi, Vermaelen, and Wolff (2010); Pennacchi (2010) show that the bank is likely to increase risks when it issues different types of junior debt, such as contingent capital and subordinated debt, but moral hazard tends to be less when issuing contingent capital than issuing subordinated debt.

Our proposed security resembles a feature of Performance Sensitive Debt(PSD), especially a risk sharing PSD. Manso, Strulovici, and Tchistyi (2010) define PSD as risk-compensating if coupon is a non-increasing, not constant function on the performance measure. Following Manso, Strulovici, and Tchistyi (2010), we define our suggested security as a risk-sharing PSD since its coupon is a non-decreasing, not constant function on the performance measure. Of course, if a coupon rate is fixed regardless of the performance measure, this is not PSD at all. Figure 2.1 illustrates the risk-sharing, risk-compensating, and non-PSD.

The majority of performance sensitive debt contracts is known as 'risk-compensating', such as as step-up bonds(*Lando and Mortensen (2005)*). The interests of step-up bonds are linked to credit rating, paying higher interest rates for the event of credit rating downgrades. In contrast, catastrophe bonds, mainly issued by insurance companies, ensure that coupons are reduced if total losses in the company surpass a pre-specified level(Froot (2001); Ibragimov, Jaffee, and Walden (2009)). Income bonds promise the full payment of the face value, but which is only paid if the issuer has enough income to pay for it[1]. Income bonds could become an extreme case of risk-sharing PSD with contingent coupons, in which the reduction in coupon payment goes to zero at the very severe financial distress. Consequently, we analyze the advantage of varying coupon rates of bonds, not only reducing the bankruptcy probability but also fully taking tax advantages of debt. This feature is very similar to catastrophe bonds(CAT) which share a state-contingent nature of an insurance policy. Following *Ibragimov, Jaffee, and Walden (2009),* two equilibria are possible in catastrophe insurance markets; a diversification equilibrium and non-diversification. In particular, a non-diversification trap is described in which the reinsurance market would not exist neither insurance be offered at all. The intervention of central agency can correct this trap. The reasons non-diversification traps emerge in catastrophe insurance markets are similar in TBTF bank cases since the diversification of risks is sub-optimal for the individual insurers(as well as TBTF banks). With the traditional finance theory, diversification efficiently eliminates risks but under some conditions; with the concave utility function (with risk-averse investors), with thin-tailed risks (with normal distributions) and without market frictions (unlimited liability, no fixed costs, no government subsidy,.etc). In the absence of these requirements, the investors choose a sub-optimal solution leading to a socially inefficient solution. Implicit government protection as well as deposit insurance scheme cause BTF or SIFIs' moral hazards. Thus, TBTF are better off not to insure themselves. Regulatory authorities should enforce banks to implement CoCos or CAT style bonds in order for them to avoid non-diversification traps.

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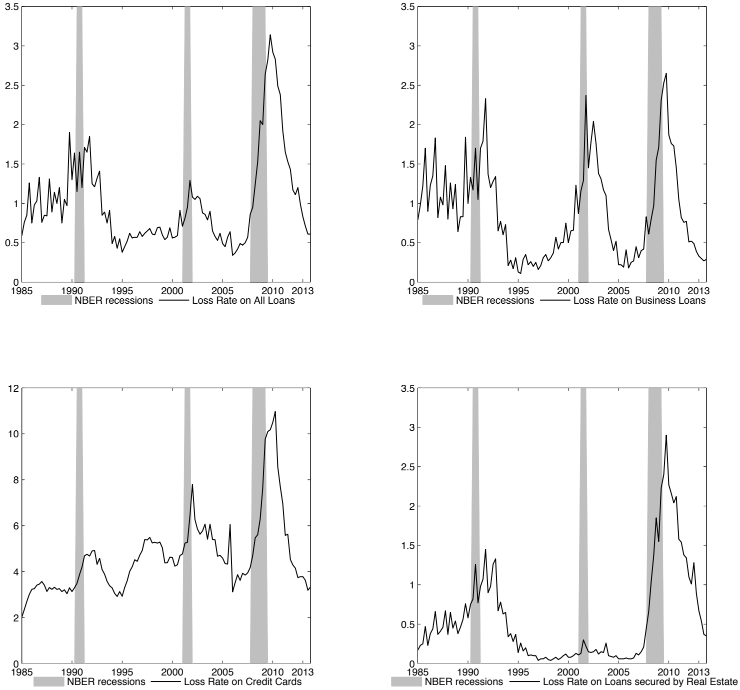
[1] Miller (1977) take income bonds as an example of the full benefit of tax credit without the bankruptcy cost disadvantages. Nonetheless, Miller puts it " ....such bonds are rarely issued."

2.3 Regime Switching in business cycle

2.3.1 Loss rate on bank loans over business cycle

Figure 2.2 provides some empirical evidence on how the movements of loss rate on bank loans are subject to macroeconomic status between 1985 and 2013. We use charge-off rates (loss rate) on bank loans from Federal Reserve Board. Charge-offs are the value of loans and leases removed from the books and charged against loss reserves, the annualized net of recoveries. NBER recession time series are composed of dummy variables that represent periods of expansion and recession. There are three NBER recessions between 1985 and 2013;from 1990Q3 to 1991Q1, from 2001Q2 to 2001Q4, and lastly from 2008Q1 and 2009Q2. The shaded areas in the figure include three recessions. The figure (a) presents total loss rates for all bank loans. Next, we disaggregated total loss rates into three subcategories; Business Loan(b), Credit Cards(c), and Real Estate Loan(d). There are three spikes in the loss rates coinciding with NBER Recessions dates. The higher loss rates on business loans are exactly fitted into the periods of three recessions, too. Nonetheless, the loss rate on real estate differs a little; it has reacted little in 1990 recessions but a very high spike in this recent financial crisis. Consequently, the historical data for charge-offs in bank loans shows that loss rates on bank loans are counter-cyclical and coincide with NBER recession periods.

The figure 2.2 confirms loss rates on bank loans change dramatically between normal and stressful times. Fluctuations in real economic parameters will be captured by the random work. The possible shifts in the behavior of economic time series imply that constant parameter models might not be plausible for capturing their jump-like behaviors. Sudden jumps into a recession, which deteriorates the firm's profit in a sudden manner, cannot be represented by the diffusion process. The firm's profit is a stationary while the jump between Good and Bad state is a non-stationary phenomenon. We incorporate this variation adopting regime-switching' approach. For instance, the ordinary business of firm runs in an ordinary manner in Good state, which is modeled with a diffusion process of parameters; $\mu_g(drift)$, $\sigma_g(volatility)$ while in Bad state of economy the parameter values are replaced with $\mu_b(drift)$, $\sigma_b(volatility)$. The shifts



(a) Total Loss Rate

(b) Loss Rate on Business Loan

(c) Loss Rate on Credit Cards

(d) Loss Rate on Real Estate

Figure 2.2: The Loss Rate on Bank Loans

Note: This figure shows that charge-off rates (loss rate) on bank loans between1985 - 2013, this data is from Federal Reserve Board's web site. We used NBER based Recession Indicators for the United States from the Period following the Peak through the Trough, from Federal Reserve Bank of St. Louis. The shaded area indicates NBER recession dates and the straight line is the loss rate(charge-off rate) annualized for bank loans.

between regimes are integrated with *Poisson* jump processes.

Moreover, the regime-switching is important in our analysis to make a distinction between insolvency and illiquidity. In our analysis, we make use of the coupon payment to restore the liquidity of banks in a Bad state, leading to a usual operation without government subsidy. However, if a bank is running badly with high losses even the business cycle is not in the same regime, signifying that any government supports for helping survive this bank is not necessary. On one hand, insolvent financial institutions are categorized as *'gone-concern'* and they should be intervened by the regulators for an efficient bankruptcy proposal. On the other hand, illiquid banks are categorized a*s 'going-concern'* and the self-revival methods of the coupon reduction and conversion would help save them.

2.3.2 How do state-contingent coupon bonds work?

Figure 2.3 illustrates both a sample path of cash level of losses from bad lending activities(left vertical axis) and a sample path of stock market index(right vertical axis). There are two types of thresholds for adjusting coupon rates; Upward and Downward. We suggest a more publicly available information as a regime-switching indicator, such as total stock market index or narrowly financial market sector index, for example, FTSE NASDAQ 500, NASDAQ Financial-100, NASDAQ Bank. A normal(recession) regime is defined as a financial market sector index passes over(under) the threshold predefined. We only allow to reduce(increase) coupon rates in times of bad(good) macroeconomic state, or in times of high(low) systemic risks prevalent. Reducing(increasing) coupon rate starts if two conditions are met; falling below(above) threshold for bank's profit level and an index of financial market stocks. By doing so, we adopt a kind of dual trigger as suggested by McDonald (2010); Pennacchi (2010). The motivation for a dual trigger in our model is to discern an cash flow insolvency from a default. If ABC bank issuing a state-contingent coupon is doing badly, but other financial industry firms are not hurt then ABC bank can not exercise lowering contingent coupons. Instead, ABC bank will follow a liquidation process. With a dual trigger in regime-switching framework, a state-contingent

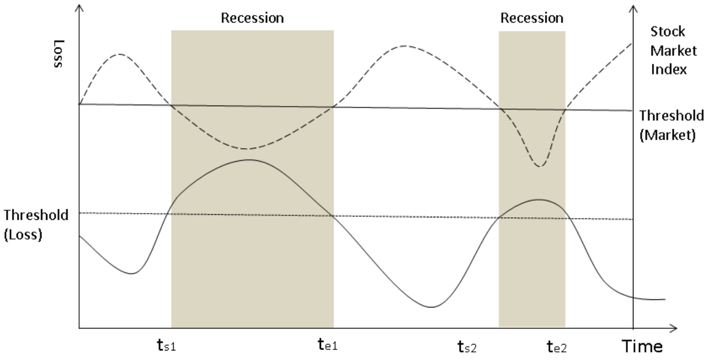


Figure 2.3: The Conversion paths and the trigger point

Note: Figure 2 illustrates a sample path of cash level of losses from bad lending activities. The losses is up and down, in particular, vastly increasing in a period of recessions. Once the losses or stock market index pass over a threshold , then the coupon rate get lowered between t_{s1} and t_{e1} in the first recession. After the recession ends, its coupon rate get adjusted upward until the second recession comes(during $t_{s2}$and t_{e2}).

coupon bond work like CAT bonds during a crisis period but standard bonds in a normal time.

How would this security have worked in the Crisis?

We do not know how much we could have reduced interests expenses for debts in 2007-2009 if we have implemented a state-contingent coupon bond beforehand. However, we can look at how much interest expenses were paid and how they did affect to bank's operation. We analyze the historical data of U.S financial industries between 1970 and 2013. This data comes from the Historical Statistics on Banking (HSOB) provides annual statistical information on the banking industry beginning in 1934. The HSOB contains aggregated data from individual financial reports filed by FDIC-insured commercial banks and savings institutions. Figure 2.4 shows how interest paid to debt has evolved during U.S banking periods between 1970 and 2013.[2] The ratio of interest expenses paid to debt to pre-tax income has risen sharply along NBER recession dates. We find that interest expenses become demanding in a bank's

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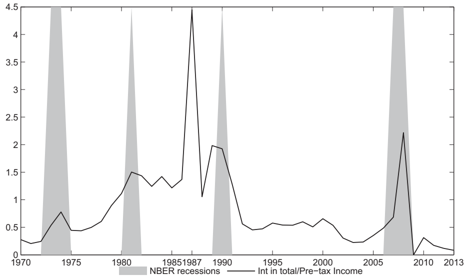
[2] We exclude the ratio of 2008 since the pre-tax income become negative.



(a) Interests Paid to Debt

Figure 2.4: Interests Paid to Debt
Note: This figure shows that Interest Expenses FDIC-Insured Commercial Banks between1934 - 2013 (dollar amounts in thousands), Data is from Table CB06, Federal Deposit Insurance Corporation.

operation in those difficult times. For example, the ratio has been doubled in three recession periods (1981, 1990, and 2007-2008) while the ratio stayed below 1 or 0.5 in normal times.

2.4 Baseline Model

2.4.1 Structural Model with Regime-Swithcing

We start by modeling the dynamics of a firm's assets and compute prices of debt and equity as contingent claims on firm value based on Merton (1974); Black and Cox (1976), and Leland (1994); Leland and Toft (1996). In Merton (1974), the firm defaults at the maturity of the debt if its asset value is less than the face value of the debt. In Black and Cox (1976), bankruptcy occurs when asset value drops to an exogenous reorganization boundary, and in Leland (1994), the time of default is chosen strategically by shareholders. The Leland type model evaluates firm's equity and debt with an endogenous default boundary in which a firm's asset flow follows a standard Brownian Motion. The dynamic capital structure model successfully applied to evaluate fixed-income debt securities in recent studies. Nonetheless, there are not much literature to study the case of regime-switching in dynamic capital structure model. We also incorporate the regime switching analysis from the investment decision under uncertain policy regimes (Hassett and Metcalf (1999); Dixit and Pindyck (1994); Pindyck (1988)).

2.4.2 Basic Model-Unlevered case

A bank produces a continuous cash flow from their lending activities which follow a Geometric Brownian motion. In particular, we consider the losses (outflow of cash) from bad lending activities as ξ.

$$d\xi_t = \mu\xi_t dt + \sigma\xi_t dW_t \tag{2.1}$$

where the process has the drift of μ and the volatility of σ. W_t is a standard Wiener process. We begin with a simple model where the drift and volatility of a recession are increased proportionately by k, a scaling factor, when the regime enters into a recession from a Good state. Here, we consider there are only two states; Good and Bad. Let P_g denote total cash (profit) when a Good state is in effect and P_b is total cash when a Bad state in effect.

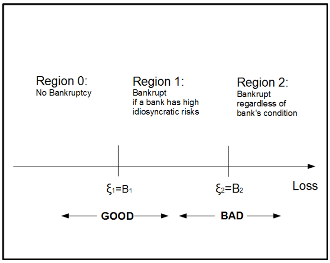
$$P_g = p - \xi \tag{2.2}$$

$$P_b = p - k\xi \tag{2.3}$$

where k is the constant, $k > 1$. p is the interest rate spread between the profit from lending and the interest pay out to depositors. A bank makse money by borrowing short-term money from depositors and making long-term loans to homeowners, consumers and businesses. The spread between loan rates and deposit rates is one way to look at gross profit margins of banks.

The switches between two states are Poisson processes. Let λ_i, the rate of entering i and l_i stand for the time to stay in state i . Starting with a state when a Good state is in effect, the probability that it will be entered into a Bad state in the next short interval of time dt is $\lambda_b dt$. On the other hand, when the recession is initially in effect, the corresponding probability that it will be recovered to a Good state is $\lambda_g dt$. The

Figure 2.5: Three Regions of Interests



Note: This figure shows three different regions separated by the bankruptcy thresholds of banks with respect to different states (Good and Bad). In Region 0, all bank are alive irrespective of potential regime shifts of uncertainty. In Region 1, a bank with high bad loans is bankrupt while the other is still alive. Finally, in Region 2, since the systemic risks are large, leading to the high losses on loans, any banks can not sustain its operation any more. All banks are bankrupt.

exponential law holds;

$$P(l_i > t) = e^{-\lambda_i t}.\ i = G,\ B \tag{2.4}$$

Depending on the scale of losses from bad loans, there are three regions of interests. Over an interval of low values of ξ, say $(0,\xi_1)$, any banks will not be bankrupt irrespective of whether a Good or Bad state is present. Over an interval (ξ_1,ξ_2), bank with loss, ξ_1, is greater than B_b will be bankrupt if a Bad state is in effect, but if not, the bank will find it optimal to operate as in a usual manner. Beyond ξ_2, the loss of bad loans will be so large that all banks will be in trouble.

In order to determine thresholds ξ_1 and ξ_2, we proceed to bank's earning processes as a function of the loss process, $V_g(\xi)$ is a value of bank with its bankruptcy threshold less than positive ξ_2 and greater than positive ξ_1, and $V_b(\xi)$, a value of bank with its bankruptcy threshold less than positive ξ_1, that is losses from bad lending activities if the severe recession or crisis is in effect.

Region 0

Consider the first region below ξ_1. In this region, both types of banks are alive. An arbitrage argument leads that

$$rV(\xi)_{g,0}dt = E(dV_{g,0}) \tag{2.5}$$

$$rV(\xi)_{b,0}dt = E(dV_{b,0}) \tag{2.6}$$

where r is a risk-free interest rate. Subscript g denotes for a Good state while subscript b for a Bad state.

Using Ito's Lemma, we derive a pair of differential equations

$$E(dV_{g,0}) = \frac{1}{2}\sigma^2\xi^2 V_{g,0}^{''} + \mu\xi V_{g,0}^{'} + p\xi + \lambda_{b,0}\left(V_{b,0} - V_{g,0}\right) \tag{2.7}$$

$$E(dV_{b,0}) = \frac{1}{2}\sigma^2\xi^2 V_{b,0}^{''} + \mu\xi V_{b,0}^{'} + pk\xi - \lambda_{g,0}\left(V_{b,0} - V_{g,0}\right) \tag{2.8}$$

Assume the expected rate of return on asset is r. The equations are rewritten as

$$rV_{g,0} = \frac{1}{2}\sigma^2\xi^2 V_{g,0}^{''} + \mu\xi V_{g,0}^{'} + p\xi + \lambda_{b,0}\left(V_{b,0} - V_{g,0}\right) \tag{2.9}$$

$$rV_{b,0} = \frac{1}{2}\sigma^2\xi^2 V_{b,0}^{''} + \mu\xi V_{b,0}^{'} + pk\xi - \lambda_{g,0}\left(V_{b,0} - V_{g,0}\right) \tag{2.10}$$

Hence, the left-hand side reflects the required rate of return for holing firm's asset per unit of time. The right-hand side is the expected change in the unlevered firm value. These equations are very similar to those expressions derived in standard contingent claims models. Nonetheless, they have an additional term $\lambda_i\left(V_j - V_i\right)$ which represents the impact of regime-switching on the value functions. That is, $\lambda_i\left(V_j - V_i\right)$ is the multiplication of the instantaneous probability of a regime-switching and the change in the value function due to a regime shift.

In order to solve these equations, let

$$V_a(\xi) = V_b\left(\xi\right)/\lambda_g + V_g\left(\xi\right)/\lambda_b \tag{2.11}$$

and

$$V_s\left(\xi\right) = V_b\left(\xi\right) - V_g\left(\xi\right) \tag{2.12}$$

By making this change of variables, two independent differential equations are derived.

$$\begin{aligned}\frac{1}{2}\sigma^2\xi^2 V_a^{''}+\mu\xi V_a^{'}-rV_a &= 0 & (2.13)\\ \frac{1}{2}\sigma^2\xi^2 V_s^{''}+\mu\xi V_s^{'}-(r+\lambda_b+\lambda_g)V_s &= 0 & (2.14)\end{aligned}$$

Each of these equations has a solution of powers of ξ that are the roots of a characteristic equation provided. In each case we have an interval of ξ that extends to 0, $(0<\xi<\xi_1)$, so we consider only the positive root. Thus

$$V_a(\xi)=C_a\xi^{\beta(0)_1} \tag{2.15}$$

$$V_s(\xi)=D_s\xi^{\beta(2)_1} \tag{2.16}$$

where C_a and $D_s$are constants to be determined, $\beta(0)_1$ is the positive root of the following characteristic equation

$$Q(0)\equiv\frac{1}{2}\sigma^2\beta(\beta-1)+\mu\beta-r=0 \tag{2.17}$$

and $\beta(1)_1$ and $\beta(1)_2$ are the roots of the following characteristic equation

$$Q(1)\equiv\frac{1}{2}\sigma^2\beta(\beta-1)+\mu\beta-(r+\lambda_{\epsilon(t)})=0 \tag{2.18}$$

where $\epsilon(t)=g,\ b$.

and $\beta(2)_1$is the positive root of

$$Q(2)\equiv\frac{1}{2}\sigma^2\beta(\beta-1)+\mu\beta-(r+\lambda_g+\lambda_b)=0 \tag{2.19}$$

With this notation, we can write down the solutions for V_n and V_r in the range $\xi\in(0,\ \xi_1)$, the region 0, as

$$\begin{aligned}V_{g,0}(x) &= \left\{\lambda_g\lambda_b C_a\xi^{\beta(0)_1}-\lambda_b D_s\xi^{\beta(2)_1}\right\}/(\lambda_g+\lambda_b)+\frac{p}{r}-\frac{\xi}{r-\mu} & (2.20)\\ V_{b,0}(x) &= \left\{\lambda_g\lambda_b C_a\xi^{\beta(0)_1}+\lambda_g D_s\xi^{\beta(2)_1}\right\}/(\lambda_g+\lambda_b)+\frac{p}{r}-\frac{k\xi}{r-\mu} & (2.21)\end{aligned}$$

the subscript $V_{g,1}$ denotes g means a good bank and 1 means the region 1, over the range $(\xi_1 < \xi < \xi_2)$. We can define the same way with $V_{b,0}$, b denoting a bad bank and 0 denoting the region 0 which represents the interval of $(0, \xi_1)$.

Region 1

Over the range $(\xi_1 < \xi < \xi_2)$, a bad bank will be bankrupt while a good bank will be alive. The arbitrage argument above is implemented for a good bank in a same way, on the other hand, the value function for a bad bank follows the early definition of the value function of bank.

$$\begin{aligned} rV_{g,1}(x) &= E(dV_{b,1}) & (2.22) \\ V_{b,1} &= p - kx & (2.23) \end{aligned}$$

By using the no-arbitrage argument similar to Region 0 analysis, we have a differential equation for a good bank in region 1. Now, we can obtain the general solution to the differential equation for the region 1, (ξ_1, ξ_2),

$$V_{g,1} = B_1 \xi^{\beta(1)_1} + B_2 \xi^{\beta(1)_2} + \frac{p}{r} - \frac{\xi}{r - \mu} \tag{2.24}$$

Region 2

Lastly, beyond the bankruptcy threshold ξ_2, $(\xi \geq \xi_2)$, all banks regardless of their types will be bankrupt and the value of banks is respectively shown as

$$\begin{aligned} V_{g,2} &= p - \xi & (2.25) \\ V_{b,2} &= p - k\xi & (2.26) \end{aligned}$$

Thus, we can solve for six unknowns including two threshold values; (ξ_1, ξ_2) by utilizing value-matching and smooth-pasting conditions.

$$V_b(\xi_b^*, c) = \alpha_b V_b(\xi_b^*) \tag{2.27}$$

$$V_g(\xi_g^*, c) = \alpha_g V_g(\xi_g^*) \tag{2.28}$$

$$\lim_{\xi \downarrow \xi_b^*} V_g(\xi_g, c) = \lim_{\xi \uparrow \xi_b^*} V_g(\xi_g, c) \tag{2.29}$$

$$\lim_{\xi \downarrow \xi_b^*} V_g^{'}(\xi_g, c) = \lim_{\xi \uparrow \xi_b^*} V_g^{'}(\xi_g, c) \tag{2.30}$$

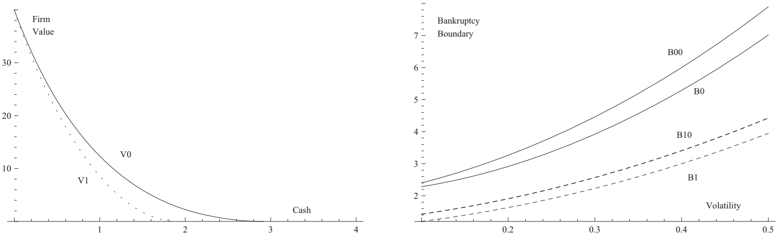
First, the value matching and smooth pasting conditions should be satisfied for $V_{b,1}$ and $V_{g,2}$ equations. Also for $V_{b,1}$ and $V_{g,2}$ the function has to be continuously differential across it and two equation should have equal values and derivatives there. In all we have six equations to determine the thresholds, ξ_1,ξ_2 and the four constants B_1, B_2, C_a, C_s.

2.4.3 Numerical Solution

Proposition 2.1. *In un-levered case, the regime-switching model characterizes the higher firm value as well as higher bankruptcy thresholds in Good state than Bad state.*

We illustrate Proposition 1 with a numerical solution. Take $r = 0.05$, $\sigma = 0.2$, $\mu = 0.02$, $\lambda_g = 0.1$, $\lambda_b = 0.1$, $p = 2$, $k = 2$, which parameters are following Dixit and Pindyck (1994). With these parameters given, the thresholds for a good and Bad states are receptively $\xi_1 = 1.63$ and $\xi_2 = 3.26$. Next, we compute comparative statistics by varying volatility and level of cash flow and risk-free rate. The first figure shows that a bank in a Good state has a higher value and higher bankruptcy threshold comparing to a bank in a Bad state as the loss on bad loan increases. The second graph illustrates changes in volatility have a positive relation with the bankruptcy threshold. However, the last figure represents the risk free interest rates influences on the bankruptcy thresholds in an opposite direction. All results confirm the traditional capital structure theory also works in a regime-switching framework.

We represent the fundamental treatment of solving the structural capital structure model with a regime switching element in this section. Also we illustrate the relationship between the value of banks in different regime and the bankruptcy threshold, the positive correlation of volatility and bankruptcy threshold and the negative



(a) Firm Value changes as cash flow changes

(b)Bankruptcy boundary changes as volatility changes

(c)Bankruptcy boundary changes as risk free rate changes

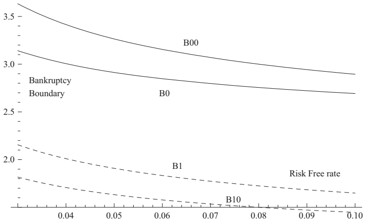


Figure 2.6: Comparative statistics of unlevered Case

Note: Figure (a) shows that bank in a Good state have a higher value and higher bankruptcy threshold comparing to a bank in a Bad state as the loss on bad loan increases. Figure (b) illustrates the change in volatility has a positive relation with the bankruptcy threshold. However, Figure (c) points out the risk free interest rates influences on the bankruptcy thresholds in a negative direction.

correlation of risk free rate and bankruptcy threshold which are line with an extant credit risk literature(Brennan and Schwartz (1978); Leland (1994); Leland and Toft (1996)).

2.5 Levered Case

Next, we consider a levered bank. For simplicity, we assume a bank issues one type of bonds with contingent coupons and equity in its capital structure (it does issue no other types of bonds). Using the results from Section 4 of Un-levered Case, we can obtain both debt and equity value of levered banks.

Region 0

We assume a simple tax structure; corporate profits are taxed at τ_c, effective dividends are taxed at τ_d, and interest payment to investors are taxed at a personal rate $\tau_{i.}$. The effective tax rate is $(1 - \tau_e) = (1 - \tau_d)(1 - \tau_c)$. In general, any claim must satisfy the partial differential equation (PDE) and we derive a pair of partial differential equations (PDEs) for each regime.

$$0 = \frac{1}{2}\sigma^2\xi^2 V_{g,0}^{''} + \mu\xi V_{g,0}^{'} + \lambda_{b,0}\left(V_{b,0} - V_{g,0}\right) - rV_{g,0} + c \tag{2.31}$$

$$0 = \frac{1}{2}\sigma^2\xi^2 V_{b,0}^{''} + \mu\xi V_{b,0}^{'} - \lambda_{g,0}\left(V_{b,0} - V_{g,0}\right) - rV_{b,0} + c \tag{2.32}$$

where c is the payout flow (coupon payment flow to debt-holders). Solving these PDEs, we have a couple of debt and equity value for each regime case. First, for the region 0 (where both banks are alive), $EG0(\xi)$ is defined as the value of equity for the bank in Good state and $DG0(\xi)$ the value of debt for the bank in a Good state, in a similar way, $EB(\xi)$ the value of equity for a Bad state and $DB(\xi)$ the value of debt which Bad state is in effect.

$$\begin{aligned} EG0(\xi) &= \left(\lambda_{g,0}\lambda_{b,0}eg_{01}\xi^{x1} - \lambda_{b}eg_{02}\xi^{y1}\right)/\left(\lambda_{g,0}+\lambda_{b,0}\right) - eg_{03}\xi \qquad (2.33) \\ &+ (1-\tau_e)(p-c)/r \\ DG0(\xi) &= \left(\lambda_{g,0}\lambda_{b,0}\,dg_{01}\xi^{x1} - \lambda_{b,0}dg_{02}\xi^{y1}\right)/\left(\lambda_{g,0}+\lambda_{b,0}\right) + (1-\tau_i)\,c/r \qquad (2.34) \end{aligned}$$

$$\begin{aligned} EB0(\xi) &= \left(\lambda_{g,0}\lambda_{b,0}eb_{01}\xi^{x1} + \lambda_{g,0}eb_{02}\xi^{y1}\right)/\left(\lambda_{g,0}+\lambda_{b,0}\right) + eb_{03}\xi \qquad (2.35) \\ &+ (1-\tau_e)(p-c)/r \\ DB0(\xi) &= \left(\lambda_{g,0}\lambda_{b,0}db_{01}\xi^{x1} + \lambda_{g,0}db_{02}\xi^{y1}\right)/\left(\lambda_{g,0}+\lambda_{b,0}\right) + (1-\tau_i)\,c/r \qquad (2.36) \end{aligned}$$

where the power x_1 stands for $\beta\,(0)_1$,and y_1 for $\beta\,(2)_1$, z_1 for $\beta\,(1)_1$ and z_2 for $\beta\,(1)_2$. Here, we change the notation for the simplicity.

Region 1

For the region 1, let $EG1(\xi)$ and $DG1(\xi)$ denote the value of debt and equity for in a Good state. Over the region 1, while the bank survives in a Good state, the bank in a Bad state is bankrupt. The solution for the ordinary differential equations only remains for the bank in a Good state. The equations represent the debt and equity values for a bank in a Good state.

$$\begin{aligned} EG1(\xi) &= eg_{11}\xi^{z1} + eg_{12}\xi^{z2} - (1-\tau_e)\,\xi/\left(r+\lambda_{b,1}-\mu\right) \qquad (2.37) \\ &+ (1-\tau_e)(p-c)/\left(r+\lambda_{b,1}\right) \\ DG1(\xi) &= dg_{11}\xi^{z1} + dg_{12}\xi^{z2} + (1-\tau_i)\,c/\left(r+\lambda_{b,1}\right) \qquad (2.38) \end{aligned}$$

For the region 1, the bank in a Bad state is bankrupt. Thus, $V_{b,1}(\xi)$ and $DB1(\xi)$ stand for the value of firm and debt in a Bad state while the equity denoted by $EB1(\xi)$ becomes worthless.

$$V_{b,1}(\xi) = p - k\xi \qquad (2.39)$$

$$DB1(\xi) = (1-\alpha)V_{b,1}(\xi) \tag{2.40}$$

$$EB1(\xi) = 0 \tag{2.41}$$

Region 2

Lastly, beyond the bankruptcy threshold ξ_2, ($\xi \geq \xi_2$), all banks under both regimes will be bankrupt and the value of banks is respectively shown as

$$\begin{aligned} V_{g,2}(\xi) &= p - \xi && (2.42) \\ V_{b,2}(\xi) &= p - k\xi && (2.43) \end{aligned}$$

Following the argument from Leland (1994), let V_B be the level of bank's asset at which bankruptcy occurs, and if bankruptcy declares, a fraction of $0 \leq \alpha \leq 1$ value will be lost as bankruptcy costs. Thus, debt-holders will have the remaining value of firm and the equity holders get nothing. This boundary condition applies that *at* $V = V_l(\xi_l)$, $DG_l(\xi_l) = (1-\alpha)V_{g,l}(\xi_l)$, $DB_l(\xi_l) = (1-\alpha)V_{b,l}(\xi_l)$. Let call ξ_l, $l = 1, 2$ as the bankruptcy threshold from Section 1 and 2. That is, the value of debt is same as un-levered case(all equity financed case) multiplied by $(1-\alpha)$, the remaining fraction of total firm value, as the bank is approaching to the bankruptcy thresholds.

2.5.1 The Value of Debt

Proposition 2.2. *When the firm's loss process is given by 2.5 and it has issued Risk-Sharing Bond with Contingent Coupon with varying coupon payment c, and let G and B denote Good and Bad state of economy, the value of corporate debt in region*

$l = 0, 1, 2$ *in three different regions is given by*

$$DG_l \begin{cases} = (\lambda_{g,0}\lambda_{b,0} \quad dg_{01}\xi^{x1} - \lambda_{b,0}dg_{02}\xi^{y1}) / (\lambda_{g,0} + \lambda_{b,0}) \\ \qquad + (1-\tau_i)\, c/r, (l = 0, \;\; \xi \leq \xi_1) \\ = \qquad dg_{11}\xi^{z1} + dg_{12}\xi^{z2} + (1-\tau_i)\, c/ (r + \lambda_{b,1}), (i = 1, \;\; \xi_1 < \xi \leq \xi_2) \\ = \qquad (1-\alpha)V_{g,2}(\xi), (l = 2, \;\; \xi > \xi_2) \end{cases} \tag{2.44}$$

$$DB_l \begin{cases} = (\lambda_{g,0}\lambda_{b,0}db_{01}\xi^{x1} + \lambda_{g,0}db_{02}\xi^{y1}) / (\lambda_{g,0} + \lambda_{b,0}) \\ + (1-\tau_i)\, c/r \qquad , (l = 0, \;\; \xi \leq \xi_1) \\ = (1-\alpha)V_{b,l}(\xi) \qquad , (l = 1, 2 \;\; \xi > \xi_1) \end{cases} \tag{2.45}$$

2.5.2 Equity Value and Default policy

We derive the value of equity following a similar process from Proposition 2.

Proposition 2.3. *When the firm's loss process is given by 2.5 and it has issued Risk-Sharing Bond with Contingent Coupon with varying coupon payment c, and let G and B denote Good and Bad state of economy, the value of equity in region* $l = 0, 1, 2$ *in three different regions is given by*

$$EG_l \begin{cases} = \left(\lambda_{g,0}\lambda_{b,0}eg_{01}\xi^{x1} - \lambda_{b,0}eg_{02}\xi^{y1}\right) / \left(\lambda_{g,0} + \lambda_{b,0}\right) - eg_{03}\xi & \\ +(1-\tau_e)(p-c)/r & ,\ (l=0,\ \ \xi \leq \xi_1) \\ = eg_{11}\xi^{z1} + eg_{12}\xi^{z2} - (1-\tau_e)\,\xi / \left(r + \lambda_{b,1} - \mu\right) & \\ +1-\tau_e)(p-c)/\left(r+\lambda_b\right) & ,\ (l=1\ \ \xi_1 < \xi \leq \xi_2) \\ = 0 & ,(l=2\ \ \xi > \xi_2) \end{cases} \tag{2.46}$$

$$EB_l \begin{cases} = \left(\lambda_{g,0}\lambda_{b,0}eb_{01}\xi^{x1} + \lambda_{g,0}eb_{02}\xi^{y1}\right) / \left(\lambda_{g,0} + \lambda_{b,0}\right) + eb_{03}\xi & \\ +(1-\tau_e)(p-c)/r & ,\ (l=0\ \ \xi \leq \xi_1) \\ = 0 & ,(l=1,2,\ \ \xi > \xi_1) \end{cases} \tag{2.47}$$

Following contingent claims model(Leland and Toft (1996); Hackbarth, Miao, and Morellec (2006); Hackbarth, Hennessy, and Leland (2007)), a shareholder's objective is to maximize their equity value and default policy is determined by a shareholder's optimal decision not to inject funds in the firm. Thus, the following two boundary conditions are satisfied:

$$\begin{aligned} EG_i^{'}\left(\xi^*\right) &= 0 \\ EB_i^{'}\left(\xi^*\right) &= 0 \end{aligned}$$

The smooth-pasting conditions provide that defaults happen along the optimal path by requiring a continuity of the slopes at the endogenous default thresholds $\xi_1^*\, and \xi_2^*$.

2.6 Numerical Results

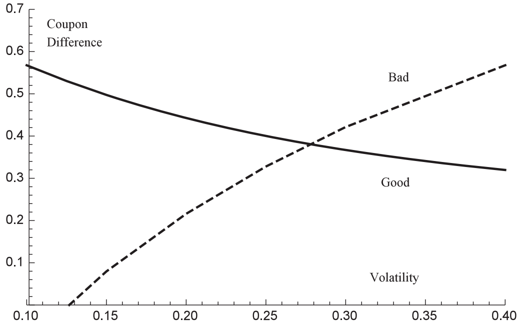
Following Section 4.3, wee compute an optimal leverage, optimal coupons, credit spreads and bankruptcy boundaries for levered case analysis. We also provide comparative statistics in Good vs Bad state as the key parameter values vary at certain interval. We take standard parameter values following Dixit and Pindyck (1994); Leland (1994); Hassett and Metcalf (1999) and compare Chen (2010) which has nine discrete states.

Proposition 2.4. *The Regime Switching model characterizes that a coupon rate drops to a lower level as the economic state transits from a Good state to a Bad state. In contrast, it jumps up a higher level when the economic state switches from a Bad state to a Good one.*

First, we solve how optimal coupons are varying in two extreme states according to changes in the volatility of underlying process. The numerical analysis confirms that the optimal coupon jumps down to a lower level from Good state to Bad state as our theory predicted. As the volatility of cash flow (σ_b) increases between 0.05 to 0.45, the optimal coupon difference between Good state and Bad state is increasing from 0 to 0.6. On the other hand, the difference is decreasing but still positive as the volatility of cash flow(σ_g) changes.

Proposition 2.5. *The Regime Switching model characterizes a counter-cyclical leverage over the business cycle.*

Next, we show how a bank decides its leverage in times of uncertain regime-shifts. We define an optimal leverage as $(D/D+E)$. The numerical analysis provides that a bank takes more debt when the volatility of earning is high in Bad state. The average leverage in Bad state is higher than Good state since hiring more debt in Bad state produces higher tax benefits at first and lower coupon payments at later. The optimal leverage gets lower in Good state while its leverage is fixed in Bad state as the volatility of cash flow in Good state (σ_g) increases between 0.05 to 0.40. The optimal leverage of bank in Bad state does not change from its optimal level of 0.83 when the volatility of cash flow in Good state varies between 0.05 and 0.40. On the other hand, a bank in Good state takes less and less debts as the uncertainty of cash



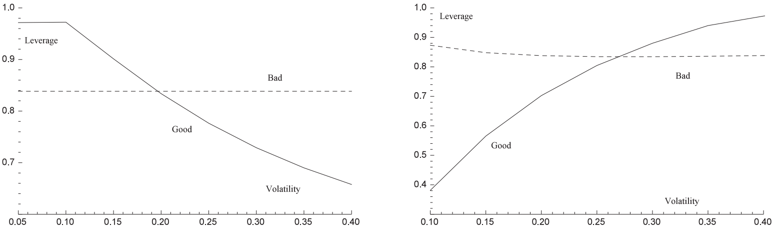
(a)Optimal coupon difference changes
as volatility changes

Figure 2.7: The Optimal Coupon Difference

Note: This figure illustrates the optimal coupon difference between Good state and Bad state as the volatility varies between 0.05 to 0.40 with the standard parameter values, $r_g = 0.05$, $r_b = 0.05$, $\sigma_g = 0.1$, $\sigma_b = 0.4$, $\mu_g = 0.01, \mu_b = -0.04$, $\lambda_g = 0.1, \lambda_b = 0.1, p_g = 2$, $p_b = 1$, $\tau_i = 0.3$, $\tau_e = 0.3$. The figure shows that an optimal coupon difference from Good state to Bad state is positive and upward sloping as the volatility of earnings in Bad state increases from 0.05 and to 0.40. On the other hand, the difference is still positive but decreasing as the volatility of earnings in Good state increases from 0.05 and to 0.40.

flow increases. The optimal leverage plummets from 0.98 to 0.60 when cash flow streams get more volatile from 0.05 to 0.40.

The second figure shows the optimal leverage when the volatility of cash flow in Bad state varies between 0.05 and 0.40. The leverage in Bad state is not changing much while a bank is taking more debt in Good state if the earning prospects are uncertain in Bad state. This figure provides intuitive results about the bank's financing policy issuing contingent coupons in case of regime changes. A bank's optimal leverage is counter-cyclical in Good state even though a bank forecasts the economic uncertainty might be very volatile. In contrast, a bank keeps a high level of leverage when a bank runs its business for long periods of Bad state regardless of the level of uncertainty in the economy. The decision to how much a bank issues external debts depends on the economic uncertainty in a good or Bad state (where a bank is operating at the moment) as well as its unknown but expected state. A bank keeps deleveraging when it is normally operated but the earning prospects get more uncertain. On the other hand, it keeps taking more debt if it expects a Bad state



Leverage as volatility changes
(a) Good state

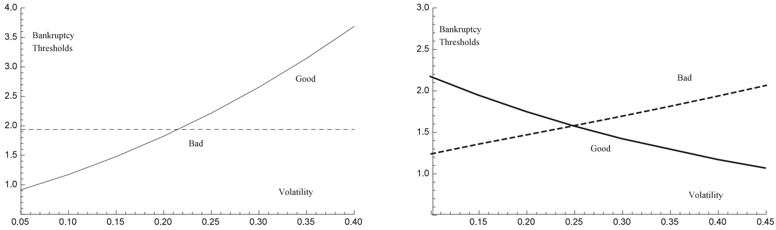
Leverage as volatility changes
(b) Bad state

Figure 2.8: The Optimal Leverage

Note: This figure illustrates the optimal leverage in Good state vs Bad state as the volatility varies between 0.05 to 0.40 with the standard parameter values, $r_g = 0.05$, $r_b = 0.05$, $\sigma_g = 0.1$, $\sigma_b = 0.4$, $\mu_g = 0.01$, $\mu_b = -0.04$, $\lambda_g = 0.1$, $\lambda_b = 0.1$, $p_g = 2$, $p_b = 1$, $\tau_i = 0.3$, $\tau_e = 0.3$. The figure shows that a bank keeps de-leveraging in Good state, while its financing decision is not affected in Bad state, as the volatility of earnings in Good state increases from 0.05 and to 0.40. On the other hand, a bank is aggressive in taking more debt in Good state while a bank's leverage is not varying much as the volatility of earnings in Bad state increases from 0.05 and to 0.40.

with high volatility of earnings. Nonetheless, the optimal leverage in Bad state keeps staying at very high when it is operated in a Bad state at present and its income process get more uncertain. Also, its optimal leverage would not change much when it expects its earning process becomes more uncertain even if its economic status switches from its current recessionary state to a Good state. Financial regulatory agencies should guide a bank to lever itself down when credit is abundant and to lever itself up when credit gets scarce. Equity holders have an incentive to increase risk when it sees a call option like feature of compensation in times of credit expansion (asset substitution). In contrasts, they have a disinvestment incentive even though a positive NPV project is available in times of credit contraction (debt overhang). Berg and Kaserer (2010) study that a certain types of Coco bonds exaggerate both the asset substitution and debt overhang problem. Our finding, a counter-cyclical leverage, helps prevent destabilizing effects from transferring wealth between equity holders and bond holders.

Proposition 2.6. *The Regime Switching model characterizes counter-cyclical default boundaries over the business cycle.*



Bankruptcy boundary as volatility changes
(a) Good state

Bankruptcy boundary as volatility changes
(b) Bad state

Figure 2.9: The Default boundaries for firms with state-contingent coupon bonds
Note: This figure illustrates default boundaries in Good state vs Bad state as the volatility varies between 0.05 to 0.45 with the standard parameter values, $r_g = 0.05$, $r_b = 0.05$, $\sigma_g = 0.1$, $\sigma_b = 0.4$, $\mu_g = 0.01, \mu_b = -0.04$, $\lambda_g = 0.1, \lambda_b = 0.1, p_g = 2$, $p_b = 1$, $\tau_i = 0.3$, $\tau_e = 0.3$. The figure shows that default boundaries increase with volatility of cash flow in its own state, while its default boundaries decrease(or does not change) with volatility of earnings in another state.

The default boundary increases with the volatility of earnings in its own state and decreases or does not change much with the current or expected volatility of earnings in other state. Merton (1974) expresses the decision to default as exercising a put option. A firm chooses higher default boundaries when its volatility of earnings gets higher since a value of put option increases with the volatility of underlying assets; a value of firm. Equity holders trade-off between retaining put option and paying interests, and giving up their rights and not paying interests any more until upon its default.

Proposition 2.7. *(Credit Spreads) The Regime Switching model characterizes a counter-cyclical credit spreads over the business cycle.*

Credit spreads are measured as yields difference between corporate bonds and risk free debt (U.S Treasuries). In dynamic capital structure theory, credit spreads calibrated have been lower and less volatile than observed one, which is called credit spread puzzle. In our numerical analysis, average credit spreads are higher than Chen (2010)'s nine state model[3]. This figure illustrates how credit spreads change in Good

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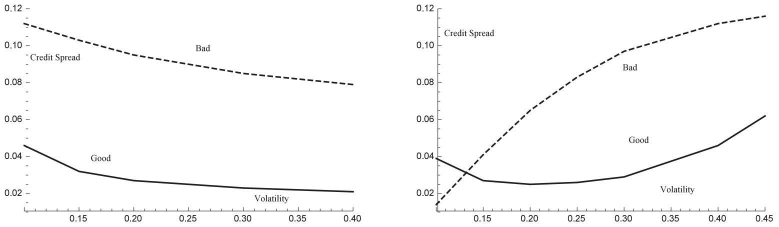
[3] Chen(2010) estimates the 10-year credit spread ranges between 37 bps and 101 bps, which he recognizes it is far short of the spread in the data (148 bps).



Credit spreads as volatility changes
(a) Good state

Credit spreads as volatility changes
(b) Bad state

Figure 2.10: Credit Spreads for firms with state-contingent coupon bonds
Note: This figure illustrates how credit spreads change in Good state vs Bad state as the volatility of earnings varies between 0.05 to 0.40 with the standard parameter values, $r_g = 0.05$, $r_b = 0.05$, $\sigma_g = 0.1$, $\sigma_b = 0.4$, $\mu_g = 0.01$, $\mu_b = -0.04$, $\lambda_g = 0.1$, $\lambda_b = 0.1$, $p_g = 2$, $p_b = 1$, $\tau_i = 0.3$, $\tau_e = 0.3$. The figure shows that credit spreads decrease from 5 percent to 2 percent in a Good state as the economic uncertainty get bigger . On the other hand, credit spreads in a Bad state increases from 1.5 percent to 11 percent as the economic uncertainty increases.

vs a Bad state as the volatility of cash flow varies between 0.05 to 0.40. The figure shows that credit spreads decrease from 450 bps to 180 bps in a Good state as the uncertainty of future earnings get larger. Average credit spreads in a Good state is very close to the observed one from data, 148 bps(Chen (2010)). On the other hand, credit spreads in Bad state increases from 1,500 percent to 11,000 bps as the uncertainty of future earnings increases from 0.05 to 0.40. The extremely high credit spreads (11 percent) measured in Bad state are exactly fitted into the empirical data; U.S High Yield BB Spread[4] reached as high as 14 percent in November 2008 and kept above 10 percent throughout 2008 and 2009 in the recent financial crisis(see **??**)

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[4] This data represents the Option-Adjusted Spread (OAS) of the BofA Merrill Lynch US Corporate BB Index, a subset of the BofA Merrill Lynch US High Yield Master II Index tracking the performance of US dollar denominated below investment grade rated corporate debt publically issued in the US domestic market. This subset includes all securities with a given investment grade rating BB. Data is retrieved from FRED, Federal Reserve Bank of St. Louis https://research.stlouisfed.org/fred2/series/BAMLH0A1HYBB/

2.7 Summary and Conclusions

We model a firm's optimal capital structure when a growth rate and volatility of earnings shift between Good and Bad state. A firm optimally issues a security with state-contingent coupon obligations. We find that, first, a firm issuing state-contingent coupon bonds, which pay out higher coupons in Good state while reduce its coupon rate in Bad state, efficiently manages its liquidity shortage in times of high systemic risks. Second, a firm optimally adjusts its leverage in a counter-cyclical way over the business cycle. This helps to stabilize asset substitution effects in times of credit expansion (Good state) while it also discourage a bank owner's disinvestment incentives in times of credit contraction (Bad state). Finally, we also contribute to explain why dynamic capital structure model can not produce reasonable credit spreads. Our proposed security modeled under uncertain regime changes achieve extremely high credit spreads (11 percent) measured in Bad state which are well-fitted into the empirical data; U.S High Yield BB Spread[5] reached as high as 14 percent in November 2008 and kept above 10 percent throughout 2008 and 2009 in the recent financial crisis. This study suggests a macro-prudential policy to regulatory agencies, by partly replacing CoCo bonds to state-contingent coupon bonds. CoCos are encouraged to be issued as recapitalization efforts for a bank when its capital cushion needs. However, CoCos have some limitations; first, they have a irreversibility from converting bonds to equities. Second, they might exacerbate both the asset substitution and debt overhang problem. Our suggested bonds with state-contingent coupons can mitigate CoCos' limitations 1) state-contingent coupons are more flexible than conversion from bond to equity. 2) a bank issuing state-contingent coupon bonds optimally has a counter-cyclical leverage ratio since this type of contingent bonds helps mitigate equity-holders' incentive to take risks in Good state while it encourages them to take a positive NPV projects in Bad state.

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[5] This data represents the Option-Adjusted Spread (OAS) of the BofA Merrill Lynch US Corporate BB Index, a subset of the BofA Merrill Lynch US High Yield Master II Index tracking the performance of US dollar denominated below investment grade rated corporate debt publically issued in the US domestic market. This subset includes all securities with a given investment grade rating BB. Data is retrieved from FRED, Federal Reserve Bank of St. Louis https://research.stlouisfed.org/fred2/series/BAMLH0A1HYBB/

Appendix

Generalized model

1. Un-Levered Case

We also consider the loss process has different drifts and volatility respectively different regimes (Normal, Recession).

$$d\xi_t = \mu_{\epsilon(t)}\xi_t dt + \sigma_{\epsilon(t)}\xi_t dW_t \tag{2.48}$$

where the process has the drift of μ and the volatility of σ. The $\epsilon(t) \in \{1, 2, \ldots, S\}$ is a finite-state continuous time Markov chain and W_t is a standard Wiener process. Here, we assume that $W(t)$ and $\epsilon(t)$ are independent. We consider the loss process has different drifts and volatility respectively different regimes (Normal, Recession). We start this analysis of an un-levered bank for its simplicity and obtain the closed solutions for the value of bank. Later, we will use this result for the levered banks which we are more interested in.

$$d\xi_t = \mu_r\xi_t dt + \sigma_r\xi_t dW_t \tag{2.49}$$

$$d\xi_t = \mu_n\xi_t dt + \sigma_n\xi_t dW_t \tag{2.50}$$

where $\epsilon(t) = r, n$. The corresponding value of bank (profit) is now defined by

$$P_r = P_n = p - \xi \tag{2.51}$$

Region 0

For the interval of $0 < \xi < \xi_1$, the corresponding differential equations are given by

$$E(dV_n) = \frac{1}{2}\sigma_n^2\xi^2 V_n^{''} + \mu_n \xi V_n^{'} + \lambda_r \left(V_r - V_n\right) \tag{2.52}$$

$$E(dV_r) = \frac{1}{2}\sigma_r^2\xi^2 V_r^{''} + \mu_r \xi V_r^{'} - \lambda_n \left(V_r - V_n\right) \tag{2.53}$$

and for $\xi \in [\xi_2, \infty]$, $V_r = V_n = p - \xi$.

Using the two differential equations, we solve V_r as a function of V_n and substituting it into the other equation which leads to a fourth-order differential equation.

$$\begin{aligned} &\frac{1}{4}\sigma_n^2\sigma_r^2 V_n^{''''} + \frac{1}{2}(\sigma_n^2\mu_r + \sigma_r^2\mu_n)V_n^{'''} \\ &+ \left(\mu_n\mu_r - \frac{\sigma_n^2\left(r+\mu_r\right) + \sigma_r^2\left(r+\mu_n\right)}{2}\right)V_n^{''} \\ &- \left(\mu_n(r + \lambda_r + \mu_r\left(r+\lambda_n\right)\right)V_n^{'} + \left(r^2 + r\left(\lambda_r + \lambda_n\right)\right)V_n = 0 \end{aligned} \tag{2.54}$$

The characteristic equation associated with is

$$Q_n\left(\beta\right)Q_r\left(\beta\right) = \lambda_n\lambda_r \tag{2.55}$$

where $Q_{\epsilon(t)}\left(\beta\right) = \lambda_{\epsilon(t)} + r - \left(\mu_{\epsilon(t)} - (1/2)\,\sigma_{\epsilon(t)}^2\right)\beta - (1/2)\,\sigma_{\epsilon(t)}^2\beta^2, (\epsilon(t) = r, n)$

Therefore, the general from of the solution is

$$V_n\left(\xi\right) = \sum_{j=1}^{4} A_j \xi^{\beta_j} \tag{2.56}$$

$$V_r\left(\xi\right) = \sum_{j=1}^{4} A_j l_j \xi^{\beta_j} \tag{2.57}$$

with

$$l_j = Q_n\left(\beta_j\right)/\lambda_n \tag{2.58}$$

for $j = 1, 2, 3, 4$

By eliminating the negative power of ξ, we have

$$V_n = A_1 \xi^{\beta_1} + A_2 \xi^{\beta_2} \tag{2.59}$$

$$V_r = A_1 l_1 \xi^{\beta_1} + A_2 l_2 \xi^{\beta_2} \tag{2.60}$$

We obtain a particular solution

$$\phi\left(\xi\right) = \frac{\lambda_n p}{r + \lambda_n} - \frac{\lambda_n \xi}{r + \lambda_n - \mu_n} \tag{2.61}$$

Region1

For $\xi_1 < \xi < \xi_2$,

$$E(dV_n) = \frac{1}{2}\sigma_n^2 \xi^2 V_n^{''} + \mu_n \xi V_n^{'} + \lambda_r \left(V_r - V_n\right) \tag{2.62}$$

$$V_r = p - \xi \tag{2.63}$$

The solution becomes

$$V_n\left(\xi\right) = C_1 \xi^{\gamma_1} + C_2 \xi^{\gamma_2} + \phi\left(\xi\right) \tag{2.64}$$

where $\gamma_k\left(k = r, n\right)$is the real roots of the characteristic equation

$$q\left(\gamma\right) = \lambda_n + r - \left(\mu_n - \left(1/2\right)\sigma_n^2\right)\gamma - \left(1/2\right)\sigma_n^2 \tag{2.65}$$

We obtain a particular solution

$$\phi\left(\xi\right) = \frac{\lambda_n P}{r + \lambda_n} - \frac{\lambda_n \xi}{r + \lambda_n - \mu_n} \tag{2.66}$$

With value matching and smooth-pasting conditions, we can determine A_1,A_2,C_1, C_2 and the bankruptcy thresholds.

2. Levered Case

We will focus on a levered case since it is shown that the overall value of levered bank is greater than the counterpart due to its tax benefit. We are interested in establishing the state-contingent coupon debt obligations, which has a benefit to increase the capital in times of financial distress. Moreover, we will extend this idea to contingent convertible bonds whether a comprehension of contingent capital would rescue the troubled TBTF institutions.

3. Six Scenarios

However, we can expect there exist six different scenarios because the different volatility and drifts according to two regimes (Normal and Recession) create six combinations of the order of the bankruptcy thresholds in un-levered and levered banks. The first case, which we have illustrated from Section above, is the usual category which it is hinted from the simple model ($BLR < BLN < BUR < BUN$), where B stands for Bankruptcy Threshold, L, levered, U, Unlevered, N, Good state and R, Recession Regime. We consider the six scenarios carefully. If the levered bank defaults and the boundary condition should be met such as $D = (1 - \alpha)\, V_U$, let $(1 - \alpha)$, where $0 < \alpha < 1$, be the fraction of asset value at the time of bankruptcy that debt-holders receive, leaving equity-holders nothing, V_U the value of unlevered bank. However, the levered bank suddenly switches to another regime then the boundary condition might not match with this conventional rule. For example, if a bank is suddenly shifting from normal to recession regime then the value of debt becomes the remaining value of unlevered bank in recession regime ($D = (1 - \alpha)\, VUR$). Therefore, we check carefully whether each scenarios we are considering corresponds to the right boundary condition for the value of debt-holder in case of bankruptcy depending on regime switching.

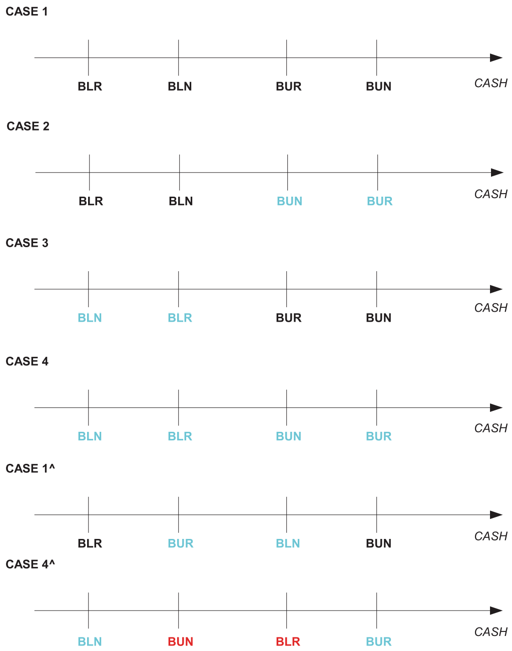
CASE 1
BLR
BLN
BUR
BUN
CASH
CASE 2
BLR
BLN
BUN
BUR
CASH
CASE 3
BLN
BLR
BUR
BUN
CASH
CASE 4
BLN
BLR
BUN
BUR
CASH
CASE 1^
BLR
BUR
BLN
BUN
CASH
CASE 4^
BLN
BUN
BLR
BUR
CASH

Figure 2.11: Six different scenarios for bankruptcy thresholds

Note: a)ELN0 (Equity, Levered Bank, Normal Region 0), ELN1 (Equity, Levered Bank, Normal Region 1), ELR (Equity. Levered Bank, Recession)
b)DLN0 (Debt, Levered Bank, Normal Region 0), DLN1 (Debt, Levered Bank, Normal Region 1), DLR (Debt, Levered Bank, Recession)
c)VUN0(total Firm Value, Un-Levered Bank, Normal Region 0),VUN1(Total Firm Value, Un-Levered Bank, Normal Region 1),VUR(Total Firm Value, Un-Levered Bank, Recession)
d)BLR(Bankruptcy Threshold, Levered Bank, Recession), BLN(Bankruptcy Threshold, Levered Bank, Normal),
e)BUR(Bankruptcy Threshold, Un-Levered Bank, Recession) ,BUN(Bankruptcy Threshold, Un-Levered Bank, Normal)

Case 1

First, we define the value of un-levered bank in this case in which the bankruptcy thresholds are in order of conventional case; both of un-levered bank whether it is in recession or not are grater than the levered bank, in addition, the value of thresholds in Good state is greater than the recession. We can represent the coefficients on the linear equation part while the coefficients on the non-linear part involved in more complex expression, thus, we will leave them for the appendix.

$$VUN0 = vun11\xi^{x_1} + vun12\xi^{x_2} + \left(\frac{\tau_e}{r_n + \lambda_n - \mu_n}\right)\xi + \left(\frac{p_n - p_n\tau_e}{r_n + \lambda_n}\right) \tag{2.67}$$

$$\begin{aligned} VUN1 &= vun21\xi^{y_1} + vun22\xi^{y_2} \\ &+ \left(\frac{\lambda_n + (r_r + \lambda_r - \mu_r)(\tau_e - 1)}{\lambda_n\lambda_r - (r_r + \lambda_n - \mu_n)(r_r + \lambda_r - \mu_r)}\right)\xi \\ &+ \left(\frac{(p_r\lambda_n + p_n(r_r + \lambda_r))(\tau_e - 1)}{r_r\lambda_n + r_n(r_r + \lambda_r)}\right) \end{aligned} \tag{2.68}$$

$$\begin{aligned} VUR &= vur01\xi^{y_1} + vur02\xi^{y_2} \\ &+ \left(\frac{\lambda_r + (r_n + \lambda_n - \mu_n)(\tau_e - 1)}{r_r(\lambda_n - \mu_n) - \lambda_r\mu_n + r_n(r_r + \lambda_r - \mu_r) - \lambda_n\mu_r + \mu_n\mu_r}\right)\xi \\ &+ \left(\frac{(p_n\lambda_r + p_r(r_n + \lambda_n))(\tau_e - 1)}{r_r\lambda_n + r_n(r_r + \lambda_r)}\right) \end{aligned} \tag{2.69}$$

With the same analysis from the simple model, we derive the value of debt and equity in each scenario as well.

$$ELN0 = eln11\xi^{x_1} + eln12\xi^{x_2} + \left(\frac{\tau_e - 1}{r_n + \lambda_n - \mu_n}\right)\xi + \left(\frac{c_n - p_n(\tau_e - 1)}{r_n + \lambda_n}\right) \tag{2.70}$$

$$\begin{aligned} DLN0 &= dln11\xi^{x_1} + dln12\xi^{x_2} + dln05\xi^{y_1} + dln06\xi^{y_2} \\ &+ \left(\frac{(-1+\alpha)\,\lambda_n}{r_n+\lambda_n-\mu_n}\right)\left(\frac{\lambda_r+(r_n+\lambda_n-\mu_n)(\tau_e-1)}{r_r\,(\lambda_n-\mu_n)-\lambda_r\mu_n+r_n\,(r_r+\lambda_r-\mu_r)-\lambda_n\mu_r+\mu_n\mu_r}\right)\xi \\ &+ \left(\frac{\frac{(p_n\lambda_r+p_r(r_n+\lambda_n))(\tau_e-1)}{r_r\lambda_n+r_n(r_r+\lambda_r)}\,(\alpha-1)\,\lambda_n+c_n\,(\tau_i-1)}{r_n+\lambda_n}\right) \qquad (2.71) \end{aligned}$$

The first pair of equation are the value of debt and equity in Good state and Region 0 since E stands for Equity, D for Debt, L for Levered, N for Normal and 0 for Region 0. In the same way, the second pair of equation are the value of debt and equity of normal bank in Region 1.

$$\begin{aligned} ELN1 &= eln21\xi^{y_1} + eln22\xi^{y_2} + \left(\frac{\lambda_n+(r_r+\lambda_r-\mu_r)\,(\tau_e-1)}{\lambda_n\lambda_r-(r_r+\lambda_n-\mu_n)\,(r_r+\lambda_r-\mu_r)}\right)\xi + \\ &+ \left(\frac{((c_r-p_r)\,\lambda_n+(r_r+\lambda_r)\,(c_n-p_n))\,(\tau_e-1)}{r_r\lambda_n+r_n\,(r_r+\lambda_r)}\right) \qquad (2.72) \end{aligned}$$

$$DLN1 = dln21\xi^{y_1} + dln22\xi^{y_2} + \left(\frac{(c_r\lambda_n+c_n\,(r_r+\lambda_r))\,(\tau_i-1)}{r_r\lambda_n+r_n\,(r_r+\lambda_r)}\right) \qquad (2.73)$$

Lastly, the pair of equations illustrate the value of debt and equity in Recession bank in region 0 and 1.

$$\begin{aligned} ELR &= elr01\xi^{y_1} + elr02\xi^{y_2} \\ &+ \left(\frac{\lambda_r+(r_n+\lambda_n-\mu_n)(\tau_e-1)}{r_r\,(\lambda_n-\mu_n)-\lambda_r\mu_n+r_n\,(r_r+\lambda_r-\mu_r)-\lambda_n\mu_r+\mu_n\mu_r}\right)\xi \qquad (2.74) \\ &+ \left(\frac{((c_r-p_r)\,(r_n+\lambda_n)+\lambda_r\,(c_n-p_n))\,(\tau_e-1)}{r_r\lambda_n+r_n\,(r_r+\lambda_r)}\right) \end{aligned}$$

$$DLR = dlr01\xi^{y_1} + dlr02\xi^{y_2} + \left(\frac{(c_n\lambda_r+c_r\,(r_n+\lambda_n))\,(\tau_i-1)}{r_r\lambda_n+r_n\,(r_r+\lambda_r)}\right) \qquad (2.75)$$

where each small letter, $n,\ r$ stands for $n=$ normal state and r =recession regime. $r=$ risk-free interest rate, $\mu=$ drift of cash flow process $\lambda$is the probability of entering each regime. c is coupon rate p is the differential between lending rate and deposit rate, $\tau_e=$ effective tax rate for corporate level, $\tau_i=$ tax rate for investors.

First of all, we compare the default triggering levels of risk-sharing PSD and standard debt by differing the coupon payment according to different regimes, for instance, $c_n > c_r$ (PSD case) or $c_n = c_r$ (standard debt case). Also, we compute the value of debt, equity and banks in three different regions by differing the coupon payment similar to the first computation. In both computations, parameters are as follows: $r_n = 0.05$, $r_r = 0.05$, $\sigma_n = 0.2$, $\sigma_r = 0.25$, $\mu_n = 0$, $\mu_r = 0.03$, $\lambda_n = 0.01$, $\lambda_r = 0.1$, $p_n = 2$, $p_r = 1$, $\tau_e = 0.3$, $\tau_i = 0.35$.

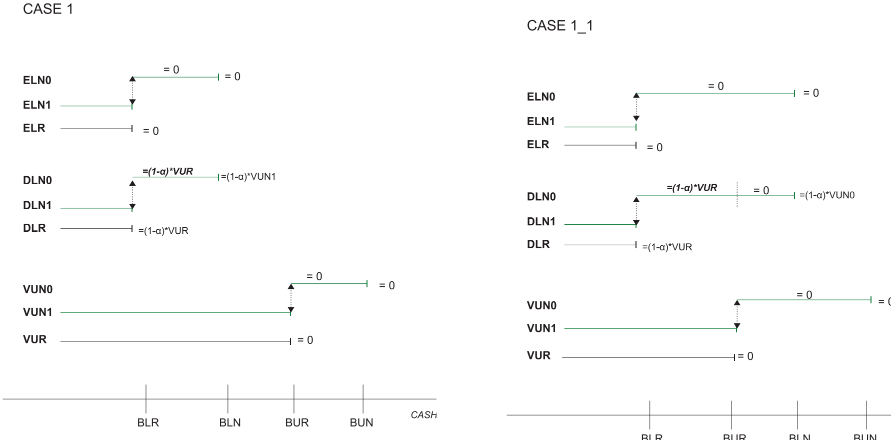
CASE 1
ELN0
ELN1
ELR
= 0
= 0
= 0
DLN0
DLN1
DLR
=(1-α)*VUR
=(1-α)*VUN1
=(1-α)*VUR
VUN0
VUN1
VUR
= 0
= 0
= 0
BLR
BLN
BUR
BUN
CASH
CASE 1_1
ELN0
ELN1
ELR
= 0
= 0
= 0
DLN0
DLN1
DLR
=(1-α)*VUR
= 0
=(1-α)*VUN0
=(1-α)*VUR
VUN0
VUN1
VUR
= 0
= 0
BLR
BUR
BLN
BUN

Figure 2.12: Boundary conditions for different cases

Note: a)ELN0 (Equity, Levered Bank, Normal Region 0), ELN1 (Equity, Levered Bank, Normal Region 1), ELR (Equity. Levered Bank, Recession)
b)DLN0 (Debt, Levered Bank, Normal Region 0), DLN1 (Debt, Levered Bank, Normal Region 1), DLR (Debt, Levered Bank, Recession)
c)VUN0(total Firm Value, Un-Levered Bank, Normal Region 0),VUN1(Total Firm Value, Un-Levered Bank, Normal Region 1),VUR(Total Firm Value, Un-Levered Bank, Recession)
d)BLR(Bankruptcy Threshold, Levered Bank, Recession), BLN(Bankruptcy Threshold, Levered Bank, Normal),
e)BUR(Bankruptcy Threshold, Un-Levered Bank, Recession) ,BUN(Bankruptcy Threshold, Un-Levered Bank, Normal)

Chapter 3

Liquidity Spirals over Moving Uncertainty: Evidence from US Financial Aggregates

We study how the instability of financial markets is related to uncertainty. We take the financial aggregate data from US stock markets into a VAR model, allowing uncertainty to continuously change behind. We find that margin requirements, market liquidity, asset prices all mutually destabilize only in the times of high uncertainty. Related findings are that in the times of low uncertainty, (1) margins and market liquidity rather stabilize each other; (2) reinforcement between margins and asset prices are much delayed in effect; and (3) asset prices and market liquidity react little each other. In brief, uncertainty fluctuations are crucial to understanding how and when liquidity spirals turn on and off in US stock markets.

3.1 Introduction

Assets become less resalable when traders have smaller access to funds. And funds become less available when assets are harder to resale. "Liquidity spirals" of this kind are now widely considered a central circuit of "instability" mechanism, through which financial markets are often led to turmoil. Reduced accessibility to loans makes selling and buying assets harder, which pushes asset prices down. And when asset prices fall, lender's capital as well as existing borrower's net worth erodes, which in turn leads to a further tightening of lending standards, thereby a further squeeze of transactions, a further drop of asset prices, and so on. In this way and back to back, the ease of obtaining funds (funding conditions), the ease of trading assets (market liquidity), and the value of the fundamentals (asset prices) affect one another. And possibly *under some circumstances*, their interaction may be amplified as much as bringing financial markets into a state of euphoria and of crisis.

Uncertainty may constitute *the circumstance.* Intuitively, financial markets will be more easily destabilized when it is harder to know the true value of the fundamentals. Brunnermeier and Pedersen (2009) provide a model in which funding conditions and market liquidity can reinforce each other when financiers are unsure regarding what made asset prices move. In this paper, we take *the uncertainty* to the fore of our empirical investigation. We ask in data, whether and how the structural relationship between funding conditions, market liquidity, and asset prices be differently shaped depending on the degree of uncertainty. Our empirical investigation is carried out at the aggregate level of a US financial market.

We use monthly data from the US stock market over the 1990-2015 period. All proxy variables are aggregates. As a proxy for (deterioration of) funding conditions, we use margin requirements for the S&P500 futures contracts; for market liquidity, Pastor and Stambaugh (2003)'s measure for market-wide aggregate liquidity; and for asset prices, the S&P500 index.[1] In addition, to construct *quantitatively discernible circumstances* with respect to the degree of uncertainty, we utilize the implied volatility of the S&P500 index options over the upcoming 30-day period (VIX).

Each of the three financial aggregates closely co-moves with the development of the VIX. As shown in Figure 3.1a, the margin requirements tend to rise immediately following or preceding the VIX hike around the outbreaks of Gulf War I (1990), Asian Crisis (1997), LTCM and Russian Crisis (1998), 9/11 Attacks (2001), Corporate scandals and convictions including Enron's (2002), and Subprime Crisis and Lehman Brothers collapse (2008). Similarly, the market-wide aggregate liquidity tends to decline around the times of the VIX hike (Figure 3.1b); so does the S&P500 index (Figure 3.1c). Provided that the VIX works well to reflect uncertainty prevailing throughout the financial world, this simple presentation clues to the dependence of

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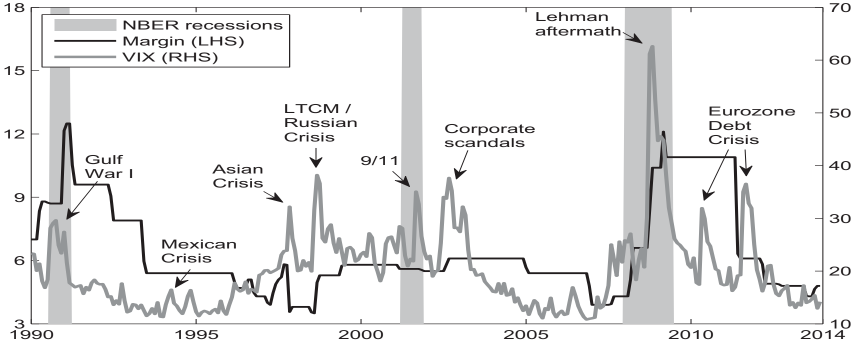
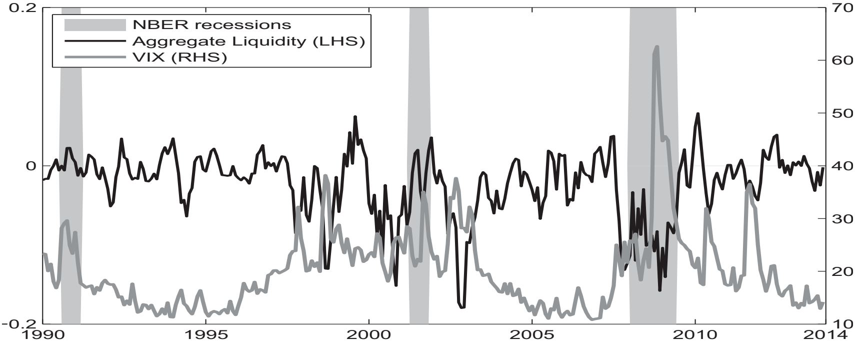
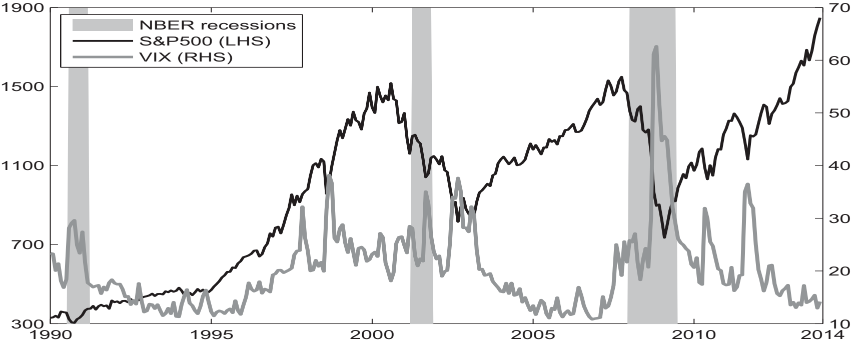
[1] Pastor and Stambaugh (2003)'s market-wide liquidity measure is one fittest to the notion of market liquidity among many candidate proxies in the literature. It essentially measures the ability to trade large quantities quickly, at low cost, and without moving the price.



(a) Margins over the VIX



(b) Market-wide Liquidity over the VIX



(c) S&P500 Index over the VIX

Note: The shaded area represents US recessions as defined by the NBER. In all panels, the gray line shows the VIX, option-price implied volatility of the S&P500 index over the upcoming 30-day period, which is quoted in percentage points and then annualized. The black line in each panel represents (a) margin requirements on the S&P500 index futures; (b) 3-month moving average of Pastor and Stambaugh (2003)'s measure for market-wide aggregate liquidity; and (c) the S&P500 index, respectively.

Figure 3.1: Financial Aggregates and the VIX

funding conditions and market liquidity and asset prices on the degree of uncertainty.[2]

However, the VIX index is a mixed pot of market uncertainty and investors' risk appetite. It is indeed referred to a fear gauge in the literature (Whaley, 2000). To distill market uncertainty, we closely follow Bekaert, Hoerova, and Lo Duca (2013) and decompose it into variance risk premium and conditional volatility. We then take a continuous mapping of the conditional volatility onto the unit interval $(0, 1)$ to proxy the "state" of financial markets with respect to uncertainty. By this mapping, the degree of uncertainty assigned becomes of measure 1 and allows a probability-like interpretation. This construction is related to our empirical method employed to explore the dependence of liquidity spirals on the uncertainty state of financial markets.

Our investigation is carried out within a vector autoregression (VAR) framework. We employ a smooth transition vector autoregression (STVAR) model developed by Auerbach and Gorodnichenko (2012). We identify shocks to the financial aggregates and differentiate their responses under *different circumstances continuously varying* with respect to the degree of uncertainty. The STVAR has a key advantage over other methods estimating VAR models for each regime separately: This method allows to capture continuous variation in the degree of being in a particular regime thereby utilizing a larger set of observations towards estimation and inference for each regime (Auerbach and Gorodnichenko, 2012).

Within our 3-variable VAR, liquidity spirals are defined at the junction of three feedback links; "margin-liquidity", "liquidity-price", and "margin-price". If markets turn illiquid in response to a tightening shock to margin requirements and the margin requirements tighten in response to a negative shock to market liquidity, we say that a "margin-liquidity" link *spirals on*; otherwise, *off*. If asset prices fall in market illiquidity and markets turn illiquid in falling asset prices, a "liquidity-price" link is said to spiral on. If the margins rise in falling asset prices and the asset prices fall in tightening funding conditions, a "margin-price" link is said to spiral on. At last, if the three links *all spiral on* at the same time, it is said that we see liquidity spirals (the instability mechanism of our interest) at present.

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[2] The VIX yields a contemporaneous correlation of 0.26 with the margin requirements, -0.35 with the market-wide liquidity, -0.13 with the S&P500 index linearly detrended. Note that the market-wide liquidity depicted in Figure 3.1b is of a 3-month moving average, with which the correlation coefficient is -0.53.

Our study finds that the liquidity spirals are on and reinforced when financial markets are surrounded with high uncertainty. It is in high uncertainty state only that the liquidity spirals turn on bringing the three links all into one instability mechanism. In low uncertainty state, each indivisible spiral is either off or weak, being delayed in effect and small in response size. In brief, the theory of liquidity spirals is confirmed at the aggregate level of financial markets. These results are robust with respect to different specifications in VAR lags and curvature parameters. The results also hold with different ordering of the VAR variables.

However, some may have doubt about appropriateness of the VIX for the present analysis. Since we want to examine the dependence of liquidity spirals on uncertainty fluctuations and *not vice versa*, there may be some endogeneity problem when using the VIX as a state variable for our STVAR. To address this issue, we repeat the same analysis using an alternative measure of uncertainty related to "national security". Admittedly, wars and terrors are most likely to remain exogenous while affecting the degree of uncertainty about the true value of the fundamentals. We find that our results remain qualitatively intact.

To our best knowledge, this study is the first one that empirically investigates the presence of liquidity spirals at the aggregate level of financial system and highlights the role of uncertainty in destabilizing financial markets. Our study contributes to a few strands of the existing literature: for example, research areas that study relationship between stock prices and market volatility, and liquidity contagion across asset markets, and so on. Our work can also shed light on the (in)effectiveness of monetary policy by means of liquidity provisions.

The rest of the paper is organized as follows: Section 2 introduces data and method and lays out the key specifications of our regime-switching model. Section 3 documents the key results about the behaviors of financial variables across different degree of uncertainty. Section 4 identifies liquidity spirals. Section 5 replaces market uncertainty with national security uncertainty and shows the robustness of the key results. Section 6 concludes.

3.2 Empirical Method

3.2.1 Uncertainty Distilled

Uncertainty is brought to the center of our empirical investigation into financial market instability mechanism. We are in particular concerned with uncertainty such that heightens when investors get more unsure about the true source of asset price movements. Unfortunately, there is no clear consensus what to be the best gauge of uncertainty (Jurado, Ludvigson, and Ng, 2015). But still upon the literature, the VIX index may be a first candidate proxy for the uncertainty in that it represents the market expectations about the volatility of asset prices over a near future period (specifically, implied from a panel of options prices on the S&P500 contracts with a maturity of one month). A growing body of literature also supports the VIX as a global state variable underlying co-movements in credit conditions and capital flows and asset prices across different economies.[3]

Nevertheless, inherently to its construction, the VIX contains both market uncertainty and risk appetite components (Bollerslev, Gibson, and Zhou, 2011; Nagel, 2012; Bekaert and Hoerova, 2014). It is constructed on the basis of a *risk-neutral* probability measure, which takes probability mass further to bad states where risk-averse investors draw higher marginal utility. The expected future realized variance based on the actual *physical* probability measure will be a better proxy for the market uncertainty. That is, we want to obtain $E_t[RV_{t+1}]$, where $E_t[\cdot]$ denotes the expectations operator conditional on date t information set and RV_{t+1} is the S&P500 realized variance in date $t+1$.

We estimate the conditional volatility by applying a simple projection method. We follow Bekaert, Hoerova, and Lo Duca (2013) and Bekaert and Hoerova (2014) and choose a two-variable model utilizing the past squared VIX and the past realized variance as predictors:

$$RV_t = \alpha + \beta_1 VIX_{t-1}^2 + \beta_2 RV_{t-1} + \epsilon_t, \tag{3.1}$$

where ϵ_t is assumed to follow an *i.i.d.* process with mean zero and a constant standard deviation.[4] The conditional volatility is obtained as the fitted values from this projection. In Section 3.2.3 later, we define regimes (and regime-switching) with respect to the degree of uncertainty on the basis of a cumulative movement of the estimated conditional volatility.

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[3] See, for example, Brunnermeier, Nagel, and Pedersen (2008); Rey (2013); Bruno and Shin (2014a,b).

[4] For the relative performance of this simple projection over other methods, refer to Bekaert,

3.2.2 Financial Aggregates

Variables of our primary interest are funding conditions, market liquidity, and asset prices. We use US financial aggregates over the sample period from January 1990 (the first appearance of the risk-neutral VIX series) until December 2015.

Regarding funding conditions, we choose margin requirements for the S&P500 futures. Increased margins represent deterioration of funding conditions in US financial markets. Specifically, the margins are expressed as a percentage fraction of the underlying S&P500 index value multiplied by the size of the contract. This construction fits into the notion of funding liquidity (the ease of obtaining funds), which is modeled as "speculator's shadow cost of capital" in Brunnermeier and Pedersen (2009). Initial and maintenance margins are the same for the Chicago Mercantile Exchange (CME) members. The data is available from the CME website.

Regarding market liquidity, we adopt Pastor and Stambaugh (2003)'s measure. Unlike other liquidity proxies, their liquidity measure takes into account the property of return reversal: i.e., the more liquid a stock is, the quicker its price impacts die out for a given trading volume. This liquidity indicator fits well into our notion of market liquidity (the ease of trading assets), essentially measuring the ease of trading large quantities quickly, at low cost, and without moving the prices. Pastor and Stambaugh (2003) obtain an estimate for each of individual stocks listed on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX), and take an equal-weighted average over them to construct a market-wide aggregate liquidity. The monthly data is available from the website of either author.

Regarding asset prices, we use the S&P500 index, of which total market capitalization amounts to a fairly large fraction of US equity markets. We obtain monthly data by averaging daily closing prices.

It might be worth to mention that among the three financial aggregates, the two proxies for market liquidity and asset prices are from equity markets and the one

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Hoerova, and Lo Duca (2013) and Bekaert and Hoerova (2014). Note also that our study uses daily closing prices data to obtain a series of monthly realized variance, whereas they use 5-minute returns data and sum daily realized variances to obtain a monthly series.

for funding conditions is from futures contracts. Unfortunately, margin requirements for US stocks are regulated by the Federal Reserve Board (so called Regulation T) and have little changed over the past four decades. In this respect, margins for US equity trading do not reflect the continuously changing forces and conditions of the financial markets. So we choose margin requirements for futures contracts, of which underlying asset is the representative US equity basket, the S&P500 index.

3.2.3 Smooth Transition VAR

We study the interplay between these financial aggregates within a VAR framework. Let FC denote the log of the margin requirements, LIQ the log of 1 plus the market-wide liquidity, and PRI the log of the S&P500 index.[5] We set Y_t =[FC_t, PRI_t, LIQ_t] for our benchmark specification. By this ordering, we assume that shocks to the S&P500 index and the market-wide liquidity have no contemporaneous effect on the margin requirements; and that shocks to the market-wide liquidity have no contemporaneous effect on the margins and the S&P500 index. This identifying assumption is consistent with the CME's margin policy, which is slowly implemented as described in Park and Abruzzo (2015). The ordering between the S&P500 index and the market-wide liquidity is made rather in consideration of information flow that changes in the asset prices are contemporaneously reflected on to the market-wide liquidity measure. Besides, we will also carry out robustness exercise with an alternative ordering of the variables.

The financial aggregates Y_t =[FC_t, PRI_t, LIQ_t] and the uncertainty distilled above are brought together to a regime-switching model. We allow the financial world to shift continuously with respect to the degree of uncertainty and employ a smooth transition vector autoregression (STVAR) model developed by Auerbach and Gorodnichenko (2012).[6] The basic specification with autoregression lag 1 is expressible as follows:

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[5] We add 1 piece-wise to the market-wide liquidity from Pastor and Stambaugh (2003) before taking logarithm because its original series fluctuates around 0. Its mean is -0.023 ranging between -0.334 and 0.201 over the 1990M01-2015M12 period. So while the impulse responses of FC and PRI can be typically read in percentage deviations from the long-run values of their corresponding original series, the case of LIQ should be read from the long-run value of 1 plus Pastor and Stambaugh (2003)'s market-wide liquidity (or alternatively, as approximate deviations in level/100 from the long-run value of the original series).

[6] Auerbach and Gorodnichenko (2012) use the STVAR to examine how different the effects are that fiscal policy have on the aggregate output in recession and expansion. We also utilize their Matlab code available in the publisher's website.

$$Y_t = A_L(L)Y_{t-1}F_L(z_{t-1}) + A_H(L)Y_{t-1}F_H(z_{t-1}) + u_t, \tag{3.2}$$

with $u_t \sim N(0, \varSigma_t)$ subject to

$$\varSigma_t = \varSigma_L F_L(z_{t-1}) + \varSigma_H F_H(z_{t-1}), \tag{3.3}$$

and

$$F_L(z_t) + F_H(z_t) = 1 \quad \text{for all } t.$$

$A_L(L)$ and $A_H(L)$ are lag polynomials that represent the VAR coefficients in two regimes, labeled "low uncertainty" L and "high uncertainty" H, respectively. $\varSigma_L$ and $\varSigma_H$ are variance-covariance matrices of disturbances in the two regimes. z_t is the log of the date t conditional volatility obtained from the projection (3.1). We use it with one period lag to prevent "contemporaneous" feedback from the key variables to the uncertainty index.

$F_L(\cdot)$ and $F_H(\cdot)$ are a continuous mapping from the uncertainty index z_t onto the unit interval $(0, 1)$ and represent the weights of being in low and high uncertainty regimes, respectively. We assume a logistic function

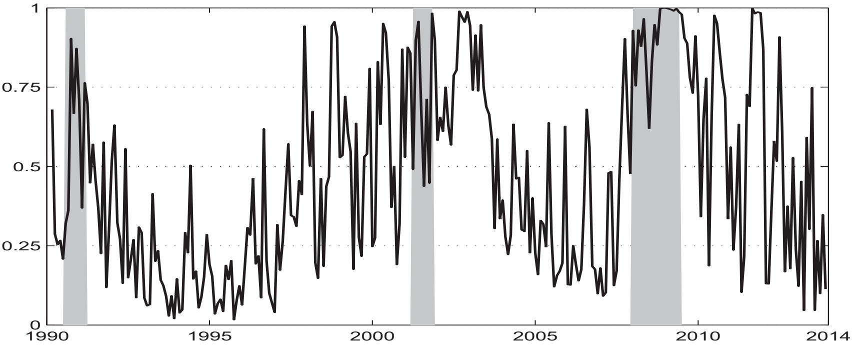
$$F_L(z_t) = \frac{\exp\left[-\theta\left(\frac{z_t-\mu_z}{\sigma_z}\right)\right]}{1+\exp\left[-\theta\left(\frac{z_t-\mu_z}{\sigma_z}\right)\right]},$$

and

$$F_H(z_t) = \frac{1}{1+\exp\left[-\theta\left(\frac{z_t-\mu_z}{\sigma_z}\right)\right]},$$

where $\theta > 0$ is a curvature parameter that governs how abruptly the financial regime switches from one to the other when the uncertainty index z_t moves over time. μ_z and σ_z are the mean and standard deviation of the uncertainty index, respectively. We take them for normalization.

Figure 3.2 shows the historical weights on the high uncertainty regime, $F_H(z_t)$. There are two notable features: First, the financial world has been faced by uncertainty not only immediately following the several major events but also often between these events. For example, we can see the uncertainty surge several times between Corporate scandals (2002) and Lehman Brothers collapse (2008). But this period has long been regarded to be a second half of the Great Moderation out of the entire



Note: The line represents the weights on the high uncertainty regime, $F_H(z_t)$. The curvature parameter θ is set to 2.

Figure 3.2: Historical Weight on High Uncertainty Regime $F_H(z_t)$

Greenspan era. Second, the measured degree of uncertainty between LTCM (1998) and 9/11 Attacks (2001) and Corporate scandals (2002) are heightened as much as the uncertainty during the 2007-08 global financial crisis. In brief, for the given mapping of the conditional volatility, the episodes of such heightened uncertainty are not of a rare phenomenon but rather historically some frequent ones. 44% of the total number of the observations has more weights on the high uncertainty regime (i.e., $F_H(z_t) > 0.5$), and the remaining 56% is the observations with $F_L(z_t) > 0.5$.

In this STVAR, Σ_L and $A_L(L)$ describe the behavior of the financial world a fairly certain regime (i.e., $F_L(z_t) \to 1$ and $F_H(z_t) \to 0$) and Σ_H and $A_H(L)$ the behavior under a sufficiently uncertain regime (i.e., $F_L(z_t) \to 0$ and $F_H(z_t) \to 1$). The key advantage of this method is that through the continuous regime-weight function $F_L(z_t) = 1 - F_H(z_t)$, it enables us to utilize a larger set of observations for estimation and inference relative to other methods estimating structural VARs for each regime separately. With respect to estimation of this model, we use an MCMC method developed by Chernozhukov and Hong (2003), which pins down a global optimum in terms of fit under regular conditions. Our estimation is based on 100,000 draws while burning the first 20% draws of them.

Our benchmark STVAR sets the curvature parameter θ to 2 and the VAR lag length to 2 and includes time trends and regime-specific intercepts. We will also conduct sensitivity analysis and robustness exercises and with various specifications.

3.3 Results

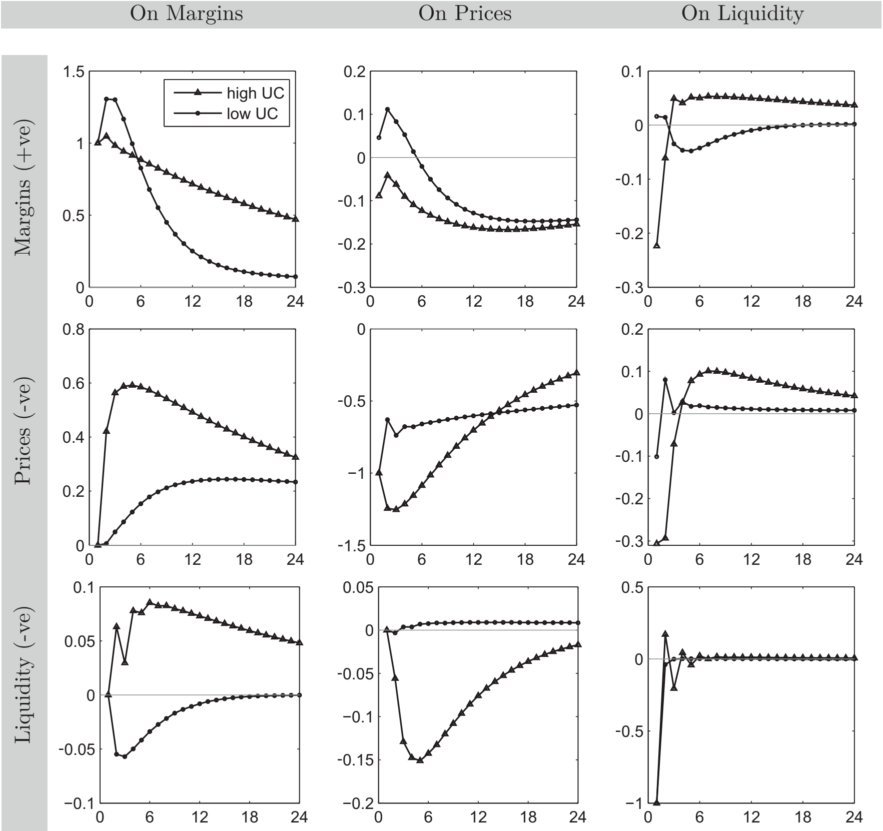
3.3.1 Impulse Responses

Our investigation into the financial instability mechanism with our 3-variable STVAR is based on the analysis of impulse responses across the two different fundamental states: high vs. low uncertainty regimes. Figure 3.3 presents the impulse responses of the financial aggregates in the two uncertainty regimes over the 24-month horizon. It is also organized in a matrix form according to the ordering of the three variables, $Y_t =$[FC$_t$, PRI$_t$, LIQ$_t$]. As constructed in Section 3.2.3 (and aforementioned in footnote 5), while the impulse responses of FC, PRI, and LIQ can be typically read in percentage deviations from the long-run paths for their corresponding original series, the case of LIQ should be seen from the long-run path for 1 plus Pastor and Stambaugh (2003)'s market-wide liquidity.

Reading out Figure 3.3, one can follow shocks in the rows and responses in the columns. A cell in the i-th row and j-th column, (i, j), indicates the behavior of the j-th variable in Y_t in response to a one-percent deviation shock to the i-th variable identified in the shaded column. In each cell, the line with triangles (circles) represents the impulse responses of the variables under the high (low) uncertainty regime. The experiments are made with a positive shock to the margins and a negative shock to each of the S&P500 index and the market-wide liquidity: that is, shocks are released to the direction of tightening funding conditions, falling asset prices, and drying market liquidity. We focus on the median impulse responses and, where worth to mention the confidence bands, will refer to appropriate figures in Appendix.

Shock to Funding Conditions

Consider first the impact of a positive shock to margin requirements. Under both uncertainty regimes, the margins jump up on impact in response to their own innovation and then decline towards the long-run value (see the cell (1,1)). But the adjustment speed differs between the two regimes. In the low uncertainty regime, the margins show a further shoot-up in the 2nd month and after then fairly quickly return to the long-run value, leading to the half-life of the shock impact in 8 months. In the high uncertainty regime, the adjustment to the long-run value is far more persistent and the half-life of the shock impact occurs almost in 24 months. This difference implies



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes (high UC and low UC). The curvature parameter θ is set to 2 and the VAR lag length 2. The trend and regime-specific intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure 3.3: Impulse Responses of the Financial Aggregates (STVAR)

that when the financial markets are faced by high uncertainty, the margin setters (central clearing parties) become more hesitant to resume the initial requirements and thus the deterioration of funding conditions last longer. However, notice that since the impulse responses are symmetrically mirrored between negative and positive shocks in our model, this result also means that once unexpectedly relaxed, the funding conditions tend to stay loosened longer in the high uncertainty regime.[7]

To the same margin shock, the asset prices respond differently under different regimes (see the cell (1,2)). In the high uncertainty regime, the asset prices fall on impact in response to the tightening of margin requirements and reached the lowest in 17 months. In the low uncertainty regime, the asset prices rise on impact and take 6 months to fall below the long-run trend in response to the margin increase. This peculiar behavior of the asset prices *for the early periods* may be because investors can better see the true source of asset price movements when the financial markets are faced by low uncertainty.[8] Then, the asset prices may not necessarily fall in response to increased margins until the fundamentals remain fine. However, the tightened funding conditions will eventually exert downward pressure on the asset prices either by making the fundamentals actually hurt or by making the asset trading hard. As shown, the asset prices make the largest deviation in the 19th month under the low uncertainty regime and their recovery path afterward nearly meets the one from the high uncertainty regime. Nevertheless, throughout the entire horizon, the downward deviations of the asset prices are smaller in the low uncertainty regime.

The market-wide liquidity also shows contrasting responses between the two regimes (see the cell (1,3)). In the low uncertainty regime, the market-wide liquidity makes little movement in response to a tightening margin shock particularly for the first two months. It starts falling in 3 months, makes the largest deviation at -0.05% in 5 months, and returns to its long-run level in 18 months. In the high uncertainty regime, the response of the market-wide liquidity is immediate. It drops on impact up to -0.25% and turn back in 3 months to 0.04% above from the long-run path.

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[7] It is also noteworthy that in the existing literature, margins are found more likely to anchor for a while when increased than when decreased (see, for example, Dudley and Nimalendran, 2011). Even though not directly dealt with in our framework, the asymmetric stickiness between the different signs of margin changes can be easily inferred from our result as far as funding conditions are more often tightened during the times of high uncertainty.

[8] Indeed, the 90% confidence band for the asset price responses is much narrower in the low uncertainty regime. See Figure A1 and A2 from Appendix and compare the two confidence bands in the upper-middle panels.

After then, the market-wide liquidity shows considerable stickiness and only slowly return to the long-run value. As such, the impulse responses of the liquidity under the two regimes differ very much in all aspects; size, timing, and converging path. The maximum drop under the high uncertainty regime is more than 5 times larger than under the low uncertainty regime. It occurs on impact when uncertainty is high but takes 5 months when uncertainty is low. Moreover, the converging paths to the long-run value are mirrored across the two regimes.

Shock to Asset Prices

Now consider a negative shock to the S&P500 index. The margin requirements are tightened in response to this loss shock under both uncertainty regimes (see the cell (2,1)). However, the margins setters are much quicker to increase the margins and to much tighter extent when they are faced by high uncertainty. In the high uncertainty regime, the maximum deviation occurs in 5 months by 0.59% above from the long-run path. In fact, throughout the entire horizon, the funding conditions remain tighter in the high uncertainty regime. In the low uncertainty regime, it takes 16 months to have the maximum response up to 0.24% deviation. This result is consistent with Park and Abruzzo (2015), who find that the central clearing parties are quicker to raise margin requirements when the markets are more volatile.

In response to the initial loss, the asset prices fall on impact under both regimes (see the cell (2,2)). But after then, the impulse responses are diverging between the two regimes. In the high uncertainty, the asset prices fall further in 2 and 3 months followed by a gradual return towards the long-run path throughout the remaining horizon, resulting in a large overall impact of the loss shock. In the low uncertainty, the asset prices start to recover in the 2nd month without hesitance but their afterward adjustments get much more sluggish. In other words, while the asset prices seem to have no doubt as to where they head for, their steps are heavy under the low uncertainty regime. This may reflect the regime's underlying feature: Investors can better see now where the initial loss shock stems from, and consider the shock this time that hit directly the asset prices as a shock to the fundamentals rather than liquidity shocks.

The same initial loss reduces the market-wide liquidity under the both regimes(see the cell (2,3)). And the overall patterns of the impulse responses appear similar between the two regimes. In the high uncertainty regime, just like a skillful diver in a swimming pool, the market-wide liquidity dives deep up to -0.31% on impact and stays underwater long before up the surface in the 4th month. In the low uncertainty regime, the market-wide liquidity falls only by -0.10% and bounces up the surface just after that, in the second month. It almost returns to its long-run path after a brief oscillation in 2-3 months. Overall, the market-wide liquidity under the high uncertainty regime goes through a far larger swing following a loss shock to the asset prices.

Shock to Market Liquidity

Release now a negative shock to the market-wide liquidity. Across the two regimes, the responses of the margin requirements are strikingly contrasting (see the cell (3,1)). In the high uncertainty regime, the margins increase following the shock, make a brief oscillation between the 2-5th month, and then reach maximum deviation in 6 months followed by gradual returning towards the long-run path. To the contrary, in the low uncertainty regime, the margins make the largest drop in 2 months after the shock and take on a gradual rise towards the long-run path.[9] The margin responses in the low uncertainty regime may reflect that all market participants including the margin setters can better see where the shock is from; this time, not from the fundamentals but from liquidity disturbance. In fact, the CME makes it clear that margins on futures contracts are set according to their "review of market volatility to ensure adequate collateral coverage" (CME, 2016, Performance Bond Rates Advisory Notice). This margin behavior is central to preventing the financial system from breaking down due to unexpected liquidity shocks and plays a key role in stabilizing the financial system when the markets are faced by relatively low uncertainty.

The asset prices are pulled down by the liquidity shock under both regimes, but the magnitude of asset price depression differs very much (see the cell (3,2)). In the high uncertainty regime, the asset prices keep falling for 4 consecutive months before resuming upward movements towards the long-run path throughout the remaining horizon. In the low uncertainty regime, the asset prices drop little to the liquidity shock and statistically do not deviate from their long-run path, throughout almost the entire horizon, at the 5% significance level (see Figure A2 in Appendix). Again, this response may be attributable to the underlying feature of the low uncertainty regime: Investors can better understand that the initial loss in their existing positions are due to an unexpected liquidity shock rather than a shock to the fundamental value of the assets they trade.

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[9] In fact, from the 3rd month on, the margin responses under the low uncertainty regime turn out not statistically deviating from their long-run path at the 5% significance level. See the impulse responses with the 90% confidence band in Figure A2 from Appendix.

The market-wide liquidity to its own shock are resilient across the two regimes (see the cell (3,3)). Under both uncertainty regimes, the market liquidity plummets on impact in response to its own innovation and then start to rebound towards the long-run value. Some minor differences are found along the converging path: A full return to the long-run value occurs in the 5th month without any wobbling in the low uncertainty regime, whereas in the high uncertainty regime it takes 9 months going through oscillatory adjustments. The resulting behaviors to its own innovation across the two regimes are consistent with the impulse responses of the market-wide liquidity to the other two shocks.

3.3.2 Robustness

We conduct robustness exercises in several directions by (i) increasing the sharpness of regime switching in the benchmark STVAR, (ii) varying the VAR lag length, (iii) including regime-specific trends in the benchmark STVAR, (iv) removing regime-specific constant terms in the benchmark STVAR; and (v) using an alternative ordering of the three variables. Overall, the results from the benchmark model essentially remain unchanged with these variations. Refer to Appendix (Figure A3 ~ A8).

3.4 Liquidity Spirals

We bring the analysis of impulse responses into the examination of liquidity spirals. In the analysis of impulse responses above, we trace the consequential behaviors of variables in response to one-off occurrence of orthogonal shocks identified with our VAR framework. The responses of a variable A to an orthogonal shock to another variable B and the responses of B to an orthogonal shock to A are presented independently of one another. But the estimated VAR coefficients on which the impulse responses are based summarize their best-fit relationships while cause-and-effects running in either direction.

We now draw attention to a bilateral link between A and B by combining A's responses to shock B and B's responses to shock A. We define liquidity spirals in terms of three indivisible links within our 3-variable STVAR: (1) A "margin-liquidity" spiral arises if markets turn illiquid in response to a tightening shock to margin requirements and the margins increase in response to a negative shock to market liquidity. (2) A "margin-price" spiral arises if the margins rise in response to a negative shock to asset prices and asset prices fall in response to a tightening shock to funding conditions. (3) A "liquidity-price" spiral arises if market turn illiquid in response to a negative shock to asset prices and asset prices fall in response to a negative shock to market liquidity. Our interest is as to whether and how these spirals behave differently across the states of low and high uncertainty. Liquidity spirals, the instability mechanism as a whole of our interest, turn on if the three indivisible links are all at work at the same time.

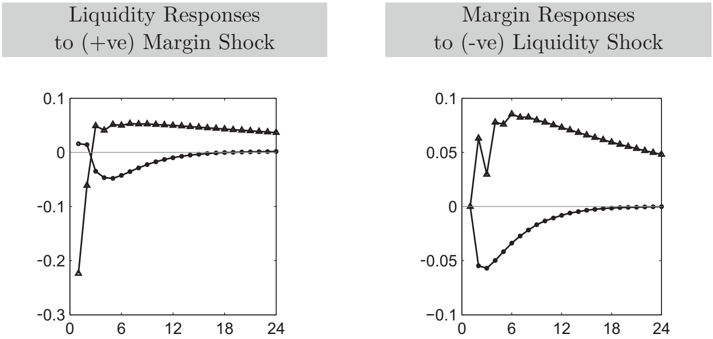
As investigations proceeded below, keep reminded of that impulse responses under each regime are symmetric with respect to the signs of a shock.

3.4.1 Three Indivisible Links

Margin-Liquidity Spiral

A margin-liquidity spiral can be examined by looking into Figure 3.3's cell (1,3) and (3,1) jointly, collected now in Figure 3.4 for convenience. In the low uncertainty regime, a tightening shock to funding conditions induces markets to turn illiquid in a few months but the funding conditions are rather relaxed immediately following an illiquidity shock. As a result, within this link, the times when liquidity shocks and liquidity responses take off in the same direction are likely to fall into the times when margin shocks and margin responses tend to neutralize their own movements. And the times when margin shocks and margin responses strengthen their own movements tend to be when liquidity responses and liquidity shocks move on to the opposite direction. In this way, margins and market liquidity stabilize each other in the low uncertainty regime. In brief, a margin-liquidity spiral turns off when the markets are faced by relatively low uncertainty.

To the contrary, in the high uncertainty regime, a tightening shock to funding conditions induces markets to immediately turn illiquid (for the first couple of months) and an illiquidity shock leads to a tightening of funding conditions. Within this



(a) Figure 3.3: cell (1,3) (b) Figure 3.3: cell (3,1)

Note: Figure 3.3's cell (1,3) and (3,1) are replicated. The horizontal axis is in months. The vertical axis is in percent.

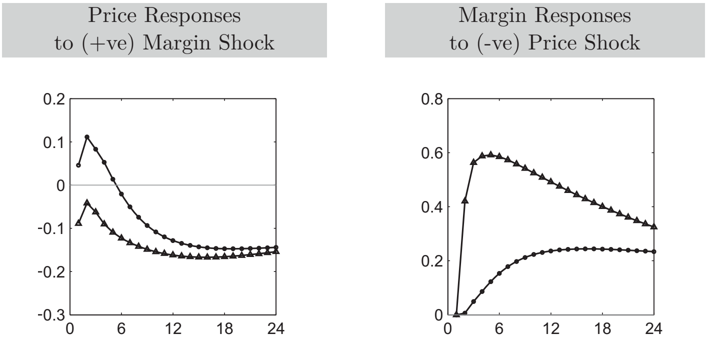
Figure 3.4: Margin-Liquidity Spiral On and Off

link, if margin shocks and margin responses happen to move in the same direction, liquidity shocks and liquidity responses are also likely to reinforce themselves, leading to a sudden liquidity dry-up or surge-up. In this way, margins and market liquidity destabilize each other when markets are faced by high uncertainty.

Still possibly, however, if two mutually stabilizing shocks (e.g., a tightening funding shock and a positive liquidity shock) hit the markets at the same time, margins and market liquidity will tend to cancel off each other, thereby spiraling effects paused even in the high uncertainty regime. This scenario has an important policy implication in line of Bernanke and Gertler (1989) and Bernstein, Hughson, and Weidenmier (2011). Fed's monetary policy leaning against the wind by means of liquidity provisions can help stop vicious reinforcement cycles emerging on the space of funding constraints and market liquidity. Its potentials for market stabilization will be more effective especially when there surrounds high uncertainty in the financial markets.

Margin-Price Spiral

A margin-price spiral can be also examined in the same manner, by looking into the cell (1,2) and (2,1) together, now collected in Figure 3.5. In the low uncertainty regime, a negative price shock tightens funding conditions but a tightening (loosening) shock to funding conditions rather boosts (reduces) asset prices for the first several months. As a mirror, a positive price shock makes funding conditions loosened but a



(a) Figure 3.3: cell (1,2)

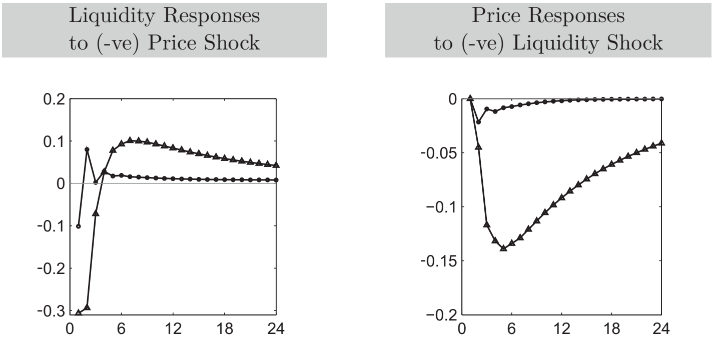
(b) Figure 3.3: cell (2,1)

Note: Figure 3.3's cell (1,2) and (2,1) are replicated. The horizontal axis is in months. The vertical axis is in percent.

Figure 3.5: Margin-Price Spiral On and Off

loosening (tightening) shock to funding conditions makes asset prices fall (rise). For all possible sets of shocks and responses within this link, margins and asset prices will not be led to a reinforcement loop. A margin-price spiral turns off in the low uncertainty regime.

In the high uncertainty regime, a negative (positive) price shock quickly tightens (loosens) funding conditions and at the same time, a tightening (loosening) shock to funding conditions suppresses (boosts) asset prices. As a result, margins and asset prices destabilize each other and a margin-price spiral emerges when the markets are faced by high uncertainty. Brunnermeier and Pedersen (2009) call such a reinforcement loop between margins and prices "loss spirals", which arise in the time of high uncertainty. An initial loss shock erodes investors' existing positions, which makes margin setters concerned about further losses and actively review their current margin requirements. Increased margins put de-leveraging pressure upon the investors trading on margin, leading them to prompt selling, further price drops, further losses, and further increase in margins. Such a margin-price spiral is also found in Wang (2015), who shows binding long margin requirements reduce stock purchases and thus drive price down.


Liquidity Responses to (-ve) Price Shock

Price Responses to (-ve) Liquidity Shock

(a) Figure 3.3: cell (2,3)

(b) Figure 3.3: cell (3,2)

Note: Figure 3.3's cell (2,3) and (3,2) are replicated. The horizontal axis is in months. The vertical axis is in percent.

Figure 3.6: Liquidity-Price Spiral On and Off

Liquidity-Price Spiral

A liquidity-price spiral can be easily demonstrated jointly from the cell (2,3) and (3,2), or from Figure 3.5. In the low uncertainty regime, asset prices respond little to a liquidity shock and market liquidity re-bounces immediately after one-off drop to a negative price shock. Within this link, the interplay between market liquidity and asset prices tend to be transitory. A liquidity-price spiral is just a spell and soon turns off, keeping the financial markets near a stable equilibrium.

To the contrary, in the high uncertainty regime, asset prices keep falling for several months in row to an illiquidity shock and market liquidity is squeezed to a negative price shock. Within this link, whenever liquidity shocks and liquidity responses take place in the same direction, price shocks and price responses will also push further their movements together, leading to price bubble or burst. In this way, market liquidity and asset prices destabilize each other in the high uncertainty regime. A liquidity-price spiral can be further strengthened when markets are populated by assets with short investment horizon and/or when investors (like hedge funds and institutional investors) have to comply with pre-set rules on tolerance level of volatility, risk, and so on (Cella, Ellul, and Giannetti, 2013).

Nevertheless, like with a margin-liquidity spiral above, if two mutually stabilizing shocks (e.g., a negative price shock and a positive liquidity shock) hit the markets at the same time, each side of asset prices and market liquidity will move to neutralize the other side's movements even in the high uncertainty regime. This leads to an important policy implication about Fed's potential role in stabilizing the financial markets. That is, when there surrounds high uncertainty in the financial markets, Fed's policy of liquidity provisions leaning against the wind can help cut in downward spirals emerging on the space of asset prices and market liquidity.

3.4.2 Liquidity Spirals and Uncertainty

Liquidity spirals emerge where the three indivisible links are all at work. Margins are destabilizing if they increase in illiquidity. Liquidity is destabilizing if it decreases in margins. A margin-liquidity spiral turns on then. As shown, this is when high uncertainty faces markets. Margins are also destabilizing if they increase in asset price drop. Asset prices are destabilizing if they fall in margins. A margin-price spiral turns on then. This is observed again when there surrounds high uncertainty in the markets. Liquidity is destabilizing if it decreases in asset price drop. Asset prices are also destabilizing if they fall in illiquidity. A liquidity-price spiral turns on then. We have shown it in the high uncertainty regime.

Lenders and margin setters tend to tighten funding conditions when markets face high volatility (CME, 2016). Reduced accessibility to funds makes selling and buying assets harder (margin-liquidity), which leads asset prices to fall (liquidity-price). And when the asset prices fall, lenders' capital as well as borrowers' existing positions erodes, which in turn leads to a further tightening of lending standards (price-margin). This will cause a further squeeze of transactions (margin-liquidity), a further drop of asset prices (liquidity-price), and so on. Such a complete form of reinforcement loops tend to be born primarily when high uncertainty faces markets.

Regarding the important role of uncertainty, Bernstein, Hughson, and Weidenmier (2011) take a different angle but reach the same conclusion with ours. Using the 19th and early 20th century data as natural experiments, Bernstein, Hughson, and Weidenmier (2011) highlight the interplay among funding constraint, market liquidity and stock prices. They find that some reinforcement loops exist among these variables, in particular, during the "harvest season" when asset market volatility was higher than other periods of year. Doing a dynamic VAR analysis, they uncover that a positive shock from funding constraint reduces both market liquidity and stock prices and a negative shock from stock prices also reduce market liquidity whereas funding liquidity is only affected by the external factor, the harvest season and real shocks. They draw attention to the role of central banks, which could potentially prevent spiraling effects and financial crises by adjusting funding conditions and combine the history of US. Bernstein, Hughson, and Weidenmier (2011) show that the interactions among the key financial variables weaken when a lender of last resort was present.

3.5 Uncertainty Measure

In this paper, we have brought uncertainty to the fore of our empirical investigation about the instability mechanism. However, there might be some measurement issues regarding uncertainty proxy. First, derivation of uncertainty from the VIX may be coarse and imperfect. Bekaert, Hoerova, and Lo Duca (2013) derive conditional volatility using a 5-minute tick data, while we use daily return data. Moreover, their simple projection method is a rule of thumb in practice. Second, when using the distilled component from the VIX as uncertainty proxy, we encounter additional identification problems to disentangle shocks to each VAR variable from shocks to the VAR regime. As well known, the VIX co-moves with almost all financial variables such as credit conditions, capital flows, and asset prices across different economies (Brunnermeier, Nagel, and Pedersen, 2008; Rey, 2013; Bruno and Shin, 2014a,b). It also tightly co-moves with each of the three financial aggregates, as presented in Figure 3.1. The financial aggregates are all too drawn from the same basket of US stocks and derivatives (the S&P500 index and futures) and the VIX is too from the S&P500 index options. This close co-movement has pros and cons: (pros) to represent uncertainty prevailing in the financial market; (cons) to mix up casual direction between liquidity spirals and uncertainty.

We want to examine the dependence of liquidity spirals on uncertainty fluctuations and *not vice versa*. To avoid such endoegeneity issue between VAR variables and VAR regime, we alternatively take a measure of uncertainty related to "national security". This uncertainty index reflects US public concerns with national security, being constructed on newspaper appearance of security-specific terms such as war, military conflict, terrorism, and so on.[10] This measure fits into the purpose of the

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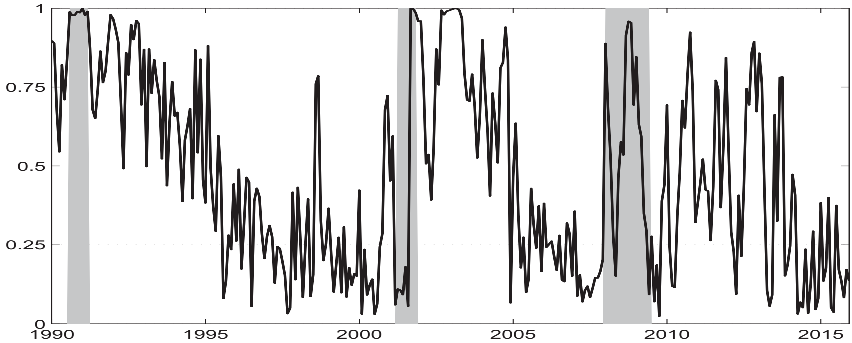
[10] The full list of related terms for this category includes national security, war, military conflict, terrorism, terror, 9/11, defense spending, military spending, police action, armed forces, base closure,



Note: The line represents the weights on the high risk-aversion regime, $F_H(z_t)$. The curvature parameter θ is set to 2.

Figure 3.7: Historical Weight on High Uncertainty on US National Security

present study because wars and terrors are most likely to remain exogenous while affecting the degree of uncertainty about the true value of the fundamentals. This property helps us examine the dependence of liquidity spirals (the structural relationship) on uncertainty (the regime), with little influence the other way around. The use of alternative measure helps also address the fitness of the decomposition method indirectly.

We bring the series in log into the STVAR system made of equations (3.2) and (3.3) together with a continuous mapping $F_L(z_t) = 1 - F_H(z_t)$ as defined before. Now $z_t = \log(\text{Uncertainty on US National Security})$. We keep all the other VAR specifications the same as made in our benchmark STVAR.

Figure 3.7 shows the historical weights on the high uncertainty regime w.r.t. US national security, $F_H(z_t)$. Compared with the history of uncertainty in Figure 3.2, the degree of national security uncertainty closely co-moves with the events including Gulf War I, 9/11 Attacks, Corporate scandals and recently Euro-zone Sovereign Crisis. However, for other times of crisis including Mexican Crisis, Asian Crisis, the national security uncertainty seem not very much related to market uncertainty. So the difference between the two uncertainty proxies is found mostly in the 1990s.

Figure 3.8 depicts the impulse responses of financial aggregates across different degree of national security uncertainty. Again, the three indivisible links can be

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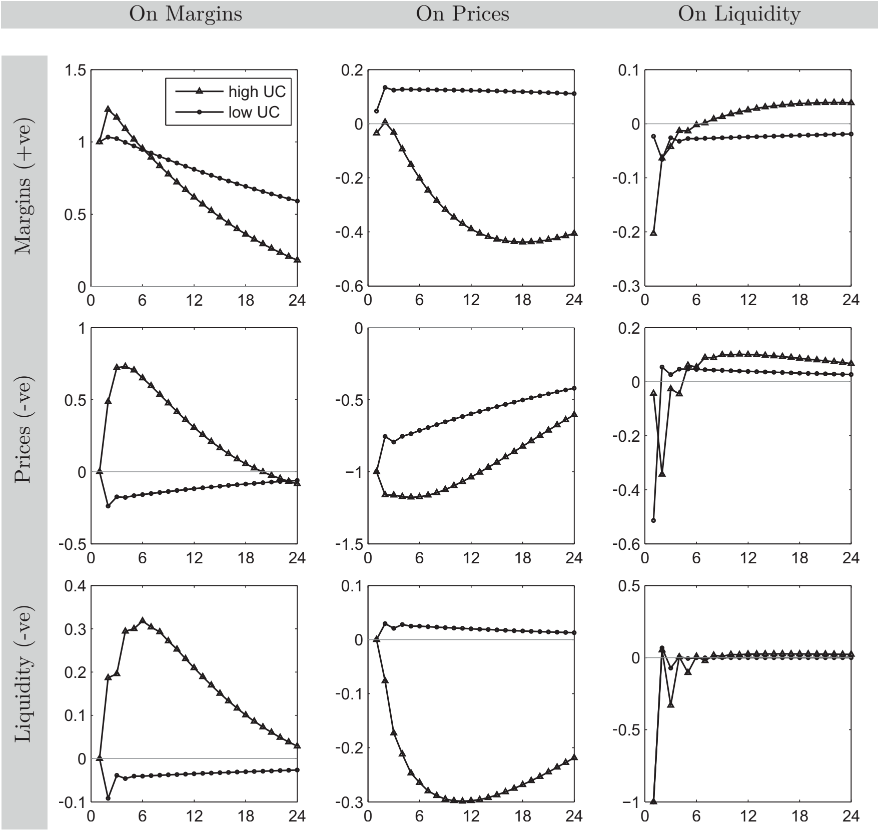
military procurement, saber rattling, naval blockade, military embargo, no-fly zone, military invasion. The monthly index is available from the website of Economic Policy Uncertainty. Baker, Bloom, and Davis (2016) detail their methodology.



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes (high UC and low UC). The curvature parameter θ is set to 2 and the VAR lag length 2. The trend and regime-specific intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure 3.8: Impulse Responses across National Security Uncertainty Regimes

examined from each set of the cells: {(1,3), (3,1)} for margin-liquidity, {(1,2), (2,1)} for margin-price, and {(2,3), (3,2)} for liquidity-price. One most notable feature is that a margin-price link shows now far more contrast between the two regimes. In the low uncertainty regime on national security, asset prices slightly rise to tightening funding conditions and the margins fall slightly in response to falling asset prices. This makes the financial system as a whole far stable against shocks. In the high uncertainty regime, the margin-price link becomes destabilizing to a greater extent compared to the previous one with market uncertainty. We also find that liquidity-price link looks more contrasting between the two different regimes.

The common results from the two different measures jointly confirm that uncertainty fluctuations are crucial to understanding how and when liquidity spirals turn on and off in US stock markets.

3.6 Conclusions

We take uncertainty to the fore of our empirical investigation into the nature of financial market instability mechanism. We ask, whether and how the ease of obtaining funds (funding conditions) and the ease of trading assets (market liquidity) and the value of the fundamentals (asset prices) take different relationships depending on the amount of uncertainty prevailing in the financial markets. To this aim, we have boiled down the financial world into a 3-variable VAR that allows uncertainty to continuously change.

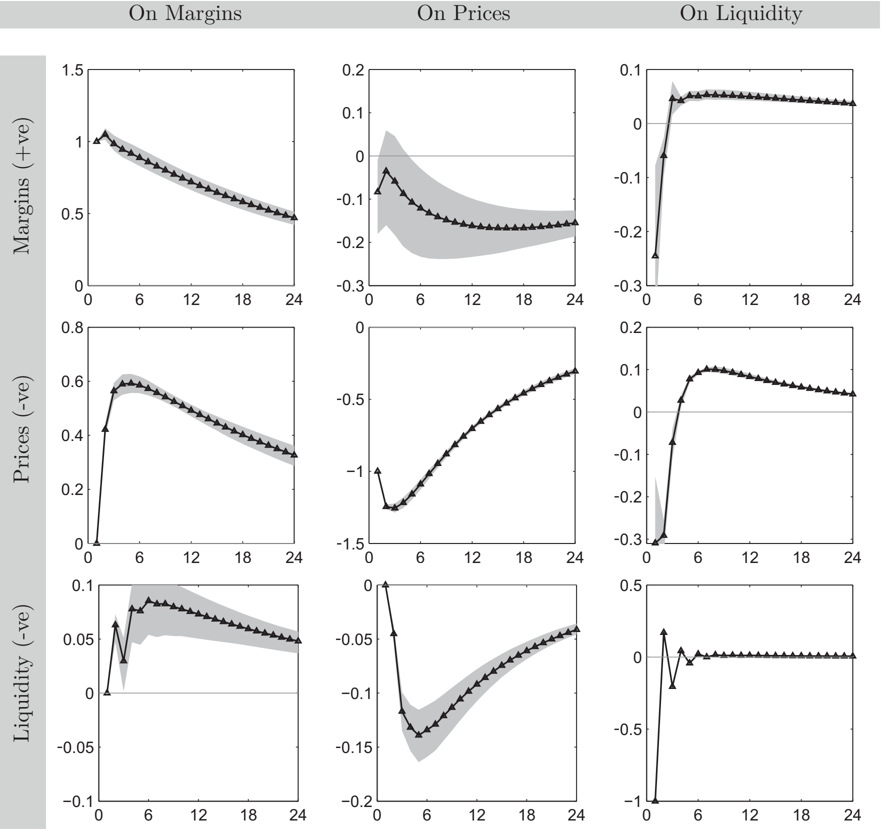
Using the US financial aggregates, we find that funding conditions, market liquidity, asset prices all mutually destabilize only in the times of high uncertainty. Related findings are that in the times of low uncertainty, (1) funding conditions and market liquidity rather stabilize each other; (2) reinforcement between funding conditions and asset prices are much delayed in effect; and (3) asset prices and market liquidity react little each other. In brief, we confirm Brunnermeier and Pedersen (2009)'s theory of liquidity spirals from the aggregate level.

To our best knowledge, this study is the first one that empirically investigates the presence of liquidity spirals at the aggregate level of financial system and highlights the role of uncertainty in destabilizing financial markets. Our study contributes to a few strands of the existing literature: for example, research areas that study relationship between stock prices and market volatility, and liquidity contagion across asset markets, and so on. Our work can also shed light on the (in)effectiveness of monetary policy by means of liquidity provisions. For example, in the model of **?**, the interdependence between funding conditions and market liquidity is central to shaping the ability of central banks to affect real economic activities.

In theory, a central bank has real effects in our economy not by its direct intervention to borrowers' constraints but by its right to control the composition of liquid assets, that is, by taking relatively illiquid assets onto its own books and bringing relatively more liquid assets into our economy. People, then with improved market liquidity, find it beneficial to allocate additional capital to illiquid assets that they would not hold otherwise, and in doing so help finance even physically irreversible capital investment. Our empirical investigation clues that the central bank's policy effectiveness in helping the economy stay around a stable equilibrium will also depend on the way of pausing spiraling effects among key financial variables especially during the times of high uncertainty. This is particularly relevant today when Fed's credibility is seriously challenged.

Appendix

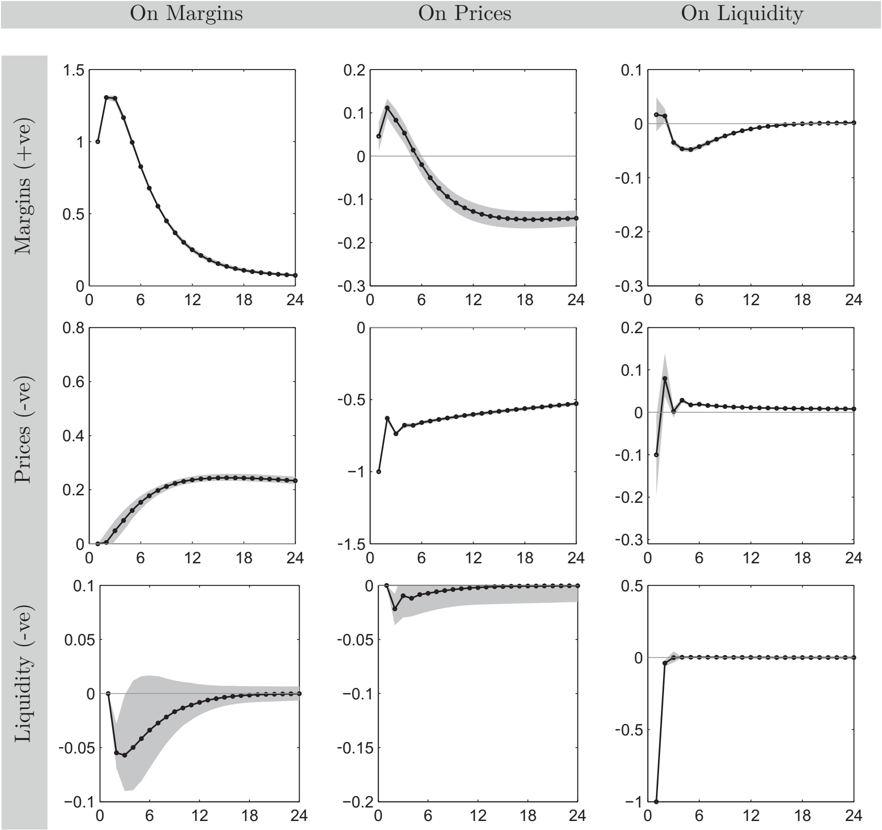
A1. Confidence Intervals (High Uncertainty Regime)



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under the high uncertainty regime. The shaded area represents the 90% confidence interval. The curvature parameter θ is set to 2 and the VAR lag length 2. The trend and regime-specific intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A1. Impulse Responses under High Uncertainty Regime

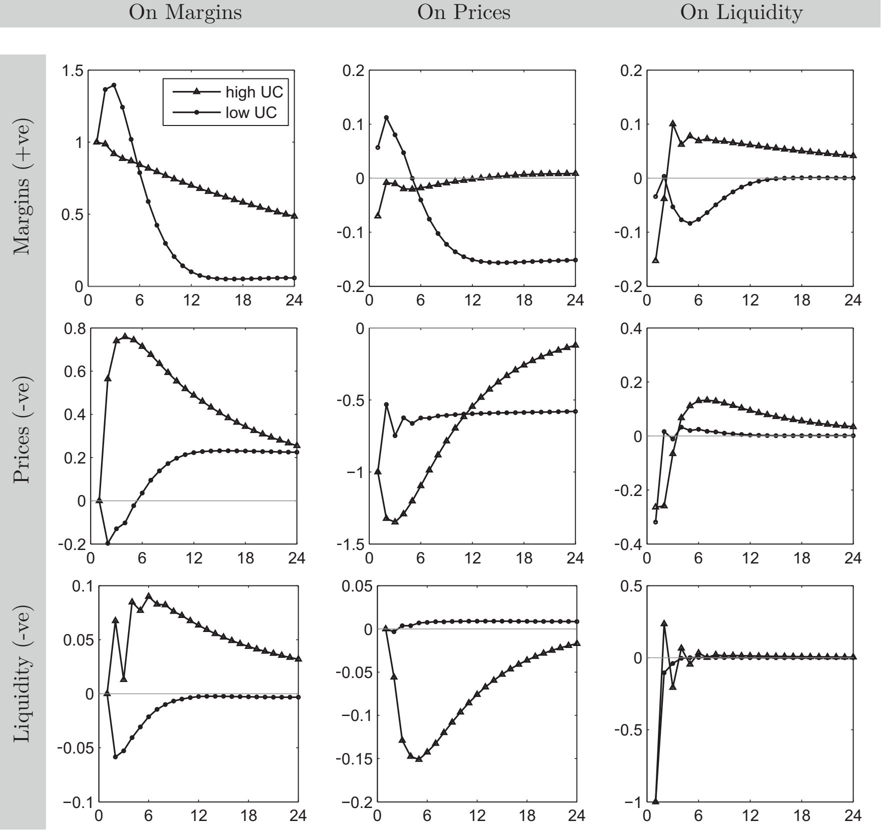
A2. Confidence Intervals (Low Uncertainty Regime)



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under the low uncertainty regime. The shaded area represents the 90% confidence interval. The curvature parameter θ is set to 2 and the VAR lag length 2. The trend and regime-specific intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A2. Impulse Responses under Low Uncertainty Regime

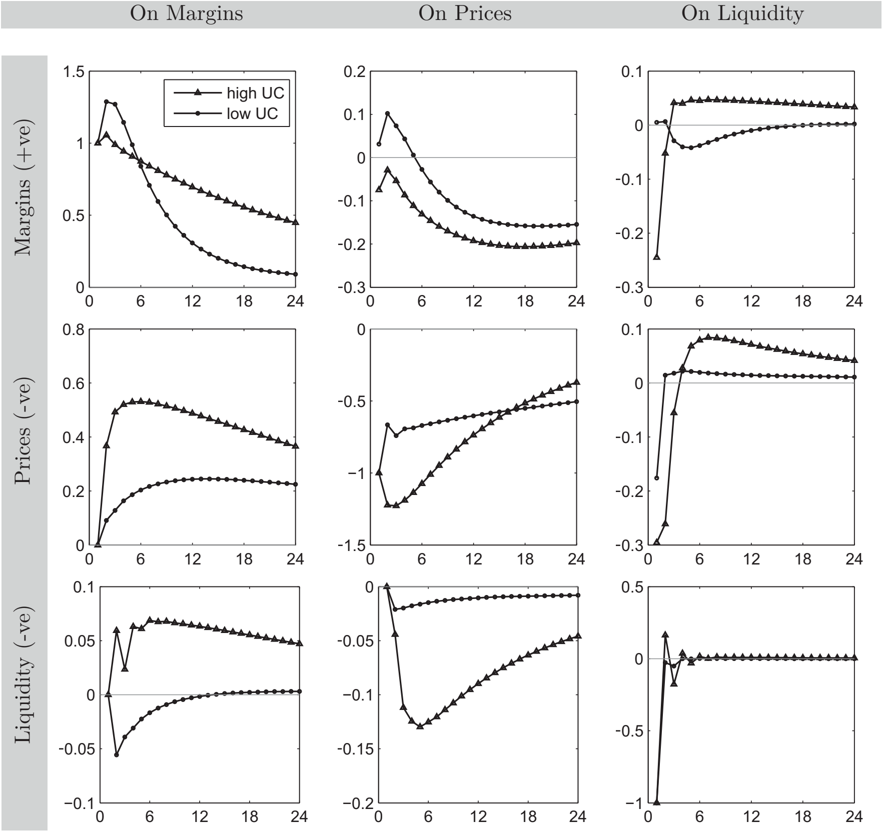
A3. Curvature Parameter (small)



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 1 and the VAR lag 2. The trend and regime-specific intercepts are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A3. IRAs with $\theta = 1$

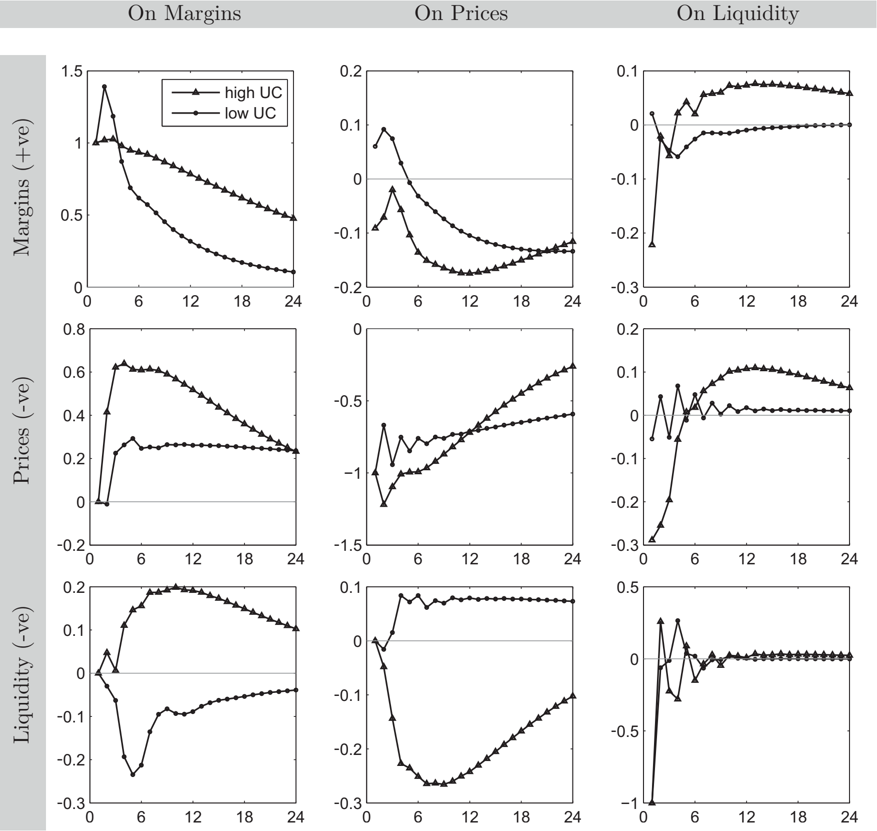
A4. Curvature Parameter (large)



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 3 and the VAR lag 2. The trend and regime-specific intercepts are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A4. IRAs with $\theta = 3$

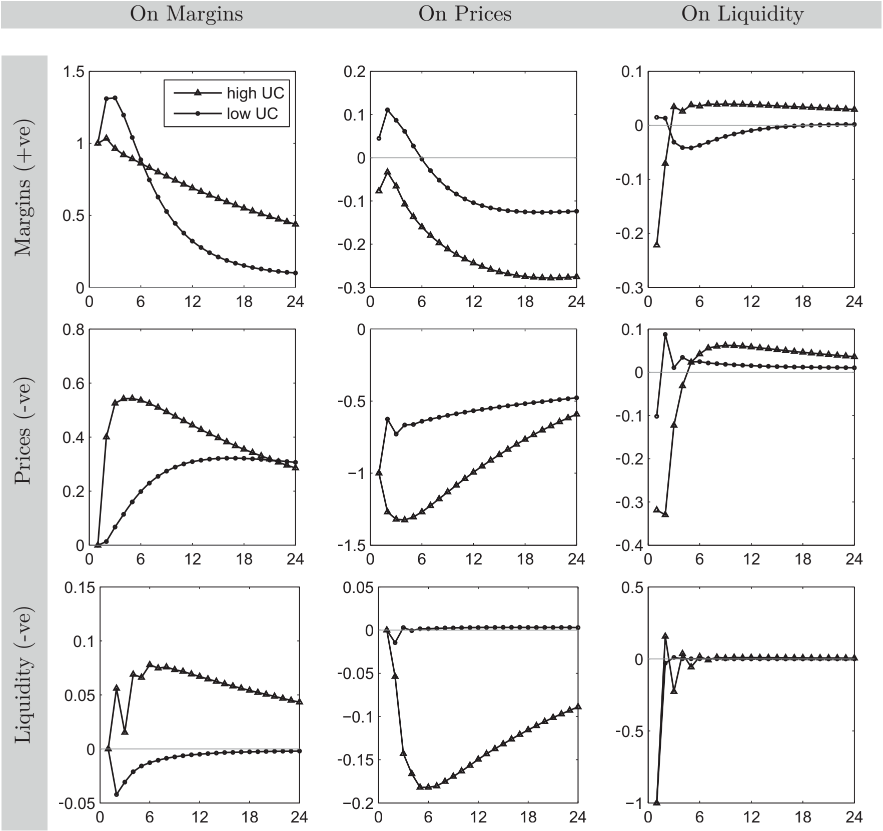
A5. VAR lag length



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 2 and the VAR lag length 3. The trend and regime-specific intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A5. IRAs with the VAR lag length 3

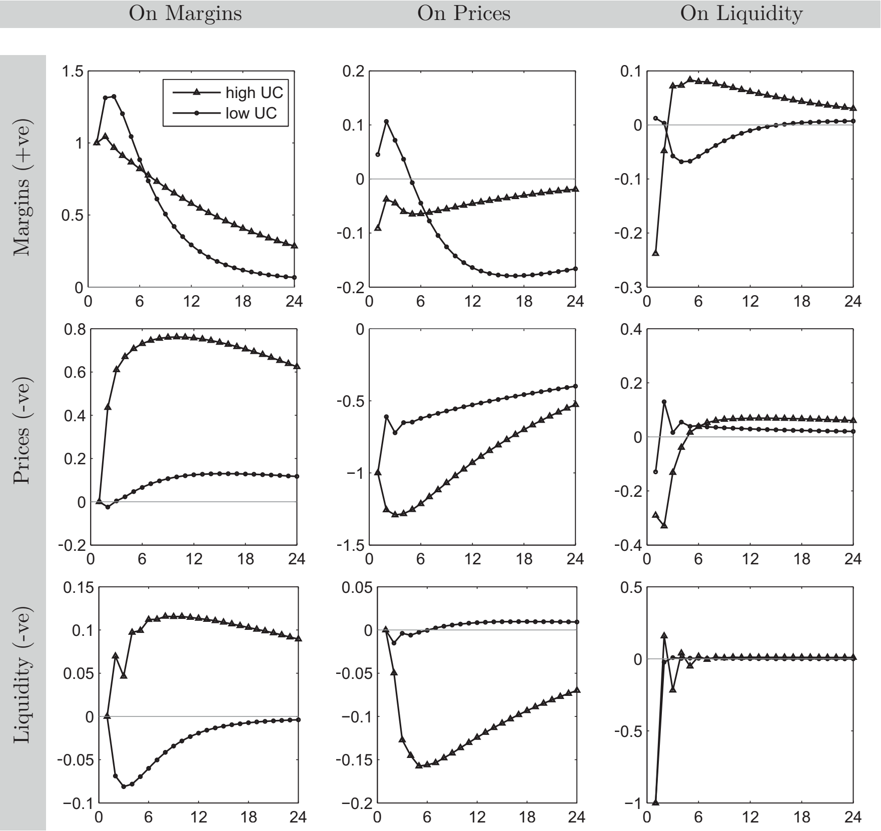
A6. Regime-specific Intercepts Removed



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 2 and the VAR lag length 2. The trend is included without regime-specific constant terms. The horizontal axis is in months. The vertical axis is in percent.

Figure A6. IRAs without regime-specific intercepts

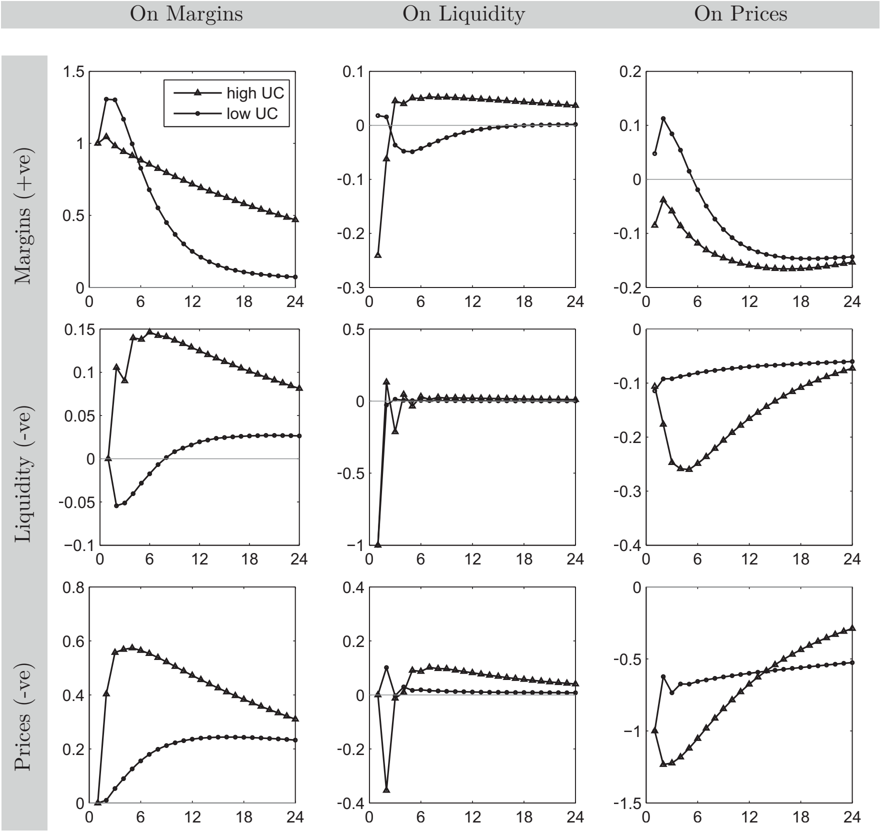
A7. Regime-specific Trends Included



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 2 and the VAR lag length 2. Apart from time trend in common, regime-specific trend and intercept are included. The horizontal axis is in months. The vertical axis is in percent.

Figure A7. IRAs with regime-specific trends

A8. Alternative Ordering of the Variables



Note: The figure depicts the impulse responses of the three financial aggregates to a one-percent deviation shock to each of the aggregates under each of the uncertainty regimes. The curvature parameter θ is set to 2 and the VAR lag length 2. The trend and regime-specific intercept are included.

Figure A8. IRAs with an alternative ordering [FC, LIQ, PRI]

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