

Securitization under Asymmetric Information over the Business Cycle

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Abstract

This paper studies the efficiency of financial intermediation through securitization in a model with heterogeneous lending opportunities and asymmetric information about the quality of securities. Issuers of securities can signal their quality by providing recourse to security buyers. I find that signaling increases the variation in the degree of asymmetric information over the business cycle, which creates the documented growth asymmetry in the cycle. In particular, in the boom stage of the business cycle, security quality remains private information and lower-quality securities accumulate on the balance sheets of lenders. This inefficient allocation of capital implies a deeper drop in output in a subsequent recession proportional to the length of the preceding boom.

Keywords: Asymmetric information; Securitization; Business cycles

JEL Classification: E32, E44, G01, G20.

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1 Introduction

Securitization, a process which converts a pool of non-tradable loans into tradable derivative securities (asset-backed securities - ABS), grew significantly in importance in the decades preceding the financial crisis of the late 2000s (Adrian and Shin, 2009). A prominent example of securitization is the conversion of pools of mortgages into mortgage-backed securities (MBS). The return on those derivative securities is based on payments of underlying loans that back the security. The central issue with securitization is the existence of asymmetric information. Originating lenders typically have better information about loan quality than buyers of securities that are backed by those loans. Since securitization effectively allows the transfer of loan default risk to security buyers, originating lenders have less incentives to maintain high lending standards. Therefore, derivative securities were designed to address precisely this problem of asymmetric information. In particular, issuers of securities provide recourse. Recourse is an obligation of the issuer of securities to retain part of the risk of losses from underlying loan defaults. Thus it protects security buyers against these losses. Since recourse provision is cheaper for issuers of securities backed by loans with lower probability of default, it can signal the underlying loan quality and improve the lending standards (Gorton and Pennacchi, 1995). Yet despite this design of securities, recent literature suggests that securitization contributed to weaker lending standards prior to the crisis (Mian and Sufi, 2009, Keys et al., 2010, Maddaloni and Peydró, 2011) implying that asymmetry of information has remained significant.

The questions addressed in this paper are twofold: how does signaling by recourse provision affect the information asymmetry in the process of securitization over the business cycle and what are its macroeconomic consequences. This paper suggests that recourse reduces the asymmetry of information. However, the efficiency of this signaling, and thus the degree of information asymmetry, varies over the business cycle. In boom stages this signaling is inefficient, information about the quality of derivative securities remains private, and low-quality loans are issued and accumulate on the balance sheets of financial intermediaries. This results in a deeper drop in output in a subsequent recession, proportional to the length of the preceding boom period. Therefore, variation in the degree of information asymmetry creates a growth rate asymmetry in the business cycle observed in the data (decreases in output are on average larger than increases in output). Indeed, skewness in annual output growth was -0.51 over the period 1953-2015 in the USA and has become more negative over time. In the last three decades (1986-2015), when securitization became more important, skewness was -1.56, while in the preceding three decades (1956-1985) it was -0.46.¹

¹Skewness is of the first-differenced log of real gross domestic product (GDP) per capita, as in Nieuwer-

This paper contributes to the existing literature in several ways. It incorporates in a tractable manner asymmetric information and signaling problems into a business cycle model with financial intermediation, in particular into the dynamic stochastic general equilibrium (DSGE) framework of Kiyotaki and Moore (2012). Another contribution is that it studies in a business cycle model both explicit (legally binding but carrying additional regulatory costs) and implicit recourse (non-contractual, with a default option, based on a reputation mechanism). It also shows how asymmetric information and the signaling channel create asymmetries in the cycle and thus it contributes to the literature on asymmetric business cycles. Finally this mechanism replicates some of the securitization market outcomes observed prior to and during the late 2000s financial crisis (namely, low lending standards in the boom which contributed to the depth of the recession). To my knowledge, existing models of securitization fail to produce these results in a rational-expectations framework.

I motivate the theoretical sections of this paper with an empirical analysis on the level of securitization deals, using data for European residential mortgage-backed securities (RMBS). I study the relationship between the explicit recourse provided to holders of RMBS in the form of overcollateralization and the delinquency rate of underlying mortgages (a proxy measure of the inverse of the quality of RMBS). Overcollateralization is the provision of collateral loans in excess of the value of derivative securities, which are used to protect security buyers from default on the underlying loans. I test the hypothesis that recourse is used as a signal of underlying loan quality, while controlling for the stage of the business cycle. According to this signaling hypothesis, issuers of high-quality securities (with lower expected delinquencies), for whom protecting against losses from defaults is relatively cheap, offer recourse to signal the quality of securities. I find that higher lagged overcollateralization is negatively correlated with the delinquency rate in the United Kingdom (UK) and Ireland, which is in line with the signaling hypothesis of recourse. Moreover, the signaling relationship disappears in both countries for the subset of deals issued in the boom. The theoretical sections endogenously produce this result for both explicit and implicit recourse. Data for the latter recourse is more anecdotal due to regulatory arbitrage feature of implicit recourse.

To study the effectiveness and macroeconomic consequences of signaling by recourse, I develop a DSGE model of financial intermediation through securitization. To clearly demonstrate the model mechanism, I also include a simple two-period model version. Both models are populated by a large number of lenders that are divided by an exogenous shock into a group that cannot make new loans and groups that can fund loans of high and low quality with high and low returns, respectively. There is no scale limit to the loan size, so optimally,

burgh and Veldkamp (2006). At the quarterly frequency this pattern of skewness is similar: -0.46 over 1956q2-1985q4 and -1.30 over 1986q1-2015q4.

lenders would want to transfer resources to those that can fund loans with a high return (low default probability). The transfer of resources among lenders is possible through securitization, which is modeled as an issuance and trading of derivative securities. Securities are backed by loan returns and their payoff is altered by recourse. Recourse is a guarantee on minimum security return, which protects the buyers of securities from losses due to underlying loan defaults.

Recourse can be explicit or implicit. Explicit recourse is legally binding but more expensive due to exogenous regulatory costs. Implicit recourse is non-contractual, with a default option, and can be enforced in a reputation equilibrium, where defaulting on a recourse is followed by a punishment in the form of an inability to sell in the primary market for derivative securities.² The modeling of recourse is analogous to the practice of ABS issuers who cover part of the default costs on loans sold in the form of securities. Higher exogenous costs of explicit recourse reflect the regulatory costs that issuers face in reality and capture the main advantage of implicit recourse, which is regulatory arbitrage.³

The financial intermediation through securitization is subject to frictions. In particular, in both models loan return is private information of the lender issuing securities so there is an asymmetry of information in the market for securities. Moreover, there is a limit on the fraction of securities that can be sold.

I show in the simple model that due to those frictions the equilibrium may be pooling, that is loan quality remains private information and as a result both high- and low-quality loans are funded. I then show that both explicit and implicit recourse can signal the quality of derivative securities and achieve a separating equilibrium, where only high-quality loans are funded. Recourse thus improves the efficiency of financial intermediation and resource allocation. However, for sufficiently low dispersion between returns of high- and low-quality loans, lenders with low-quality loans find mimicking lenders with high-quality loans more attractive. Therefore sustaining a separating equilibrium would require levels of implicit recourse so high that they cannot be enforced through reputation, or levels of explicit recourse that are too expensive. As a result, the equilibrium remains pooling.

In the full dynamic model I introduce long-term loans, aggregate productivity shock and cross-sectional loan return dispersion shock that produces the documented countercyclical

²See, for example, Higgins and Mason (2004) for concrete cases of implicit credit recourse or Brunnermeier (2009) for implicit liquidity recourse. Gorton and Souleles (2006) are among the first to show in a simple theoretical model that implicit recourse can be an equilibrium result in a repeated game due to the reputation concerns of issuers.

³The problem of lenders in the model including recourse provision could be applied also to collateralized debt or repo agreements. However, the sale of securitized assets remains the main application for the quantitative results of the paper as issues with mortgage-backed securities had arguably the largest macroeconomic impact during the crisis.

loan return dispersion. This variation in dispersion, in the context of business loans, can be motivated by the empirical evidence in Bloom (2009) and Bloom et al. (2012), who find that the second moments of firms' total factor productivity (TFP) in the economy are countercyclical. In the context of loans to households, it can be motivated by the literature on the countercyclicality of earning risks, in particular by Guvenen et al. (2014), showing that the left-skewness of idiosyncratic income shocks is countercyclical. That means that while in recessions an average household (or firm) has a slightly lower income (productivity), a subset of households (firms) have significantly lower incomes (productivity). Loans to the latter subset are more prone to delinquencies, such as in Nakajima and Ríos-Rull (2014), generating a countercyclical dispersion of loan returns.

Due to productivity shock, which positively affects return on all loans, lending and securitizing become more profitable in the boom stage of the business cycle. As a result, under asymmetric information, lenders with low-quality lending opportunities are more likely to lend, and more low-quality loans are funded, which worsens the efficiency of resource allocation. This result is reinforced by the countercyclical loan return dispersion. When booms are characterized by lower dispersion, lenders with low-quality loans find lending even more attractive, which further worsens the efficiency of resource allocation in booms relative to recessions. In the calibrated model, when recourse is not available, model equilibrium is pooling in both booms and recessions with slightly more low-quality loans issued in boom. Provision of recourse achieves a separating equilibrium in recessions, but the equilibrium remains pooling in the boom stage of the business cycle.

Since the efficiency of signaling varies over the cycle, signaling amplifies the time variation in asymmetric information, which especially in the presence of countercyclical dispersion in loan returns causes an asymmetry in the business cycle. Indeed, investment in low-quality loans has only mild negative effects on the output as long as the economy stays in a boom, since return dispersion among loans of both qualities is small. However, the effect of this accumulated stock of low-quality loans becomes more pronounced in the subsequent downturn of the economy, which is thus deeper. As a result, the longer the boom, the larger the share of lower-quality loans on lender balance sheets and the deeper will be the subsequent downturn.

Related literature. The paper is related to the extensive literature on the adverse selection in asset markets and financial intermediation, including Leland and Pyle (1977) and Myers and Majluf (1984) and, more precisely in the context of securitization, Gorton and Pennacchi (1995), DeMarzo and Duffie (1999) and DeMarzo (2005), among others. In this paper, originators of securitized assets have reputational concerns similar to Chari et al.

(2014) and Ordoñez (2014). Unlike in Chari et al. (2014), in this paper and in Ordoñez (2014) reputation helps lenders selling high-quality securities to send a signal about the quality of securities. Yet while Ordoñez (2014) focuses on the fragility of reputation-based banking in a recession, this paper shows that the signaling efficiency varies over the business cycle, finds a variation in the degree of information asymmetry over the cycle and studies its dynamic implications. Bigio (2013) also uses dispersion shocks in a model with financial intermediation and asymmetric information. He finds that higher dispersion worsens the adverse selection problem and leads to a recession. In contrast, my model features signaling, which is more effective when the dispersion is larger.

One of the key results of this paper—inefficient allocation of capital in the boom—is related to the empirical evidence on the deterioration of bank lending standards during the boom stage of the business cycle (Lown and Morgan, 2006). Furthermore, this paper presents a mechanism for explaining inefficient allocation of capital in a boom that is alternative to those existing in the theoretical literature (e.g., Dell’Ariccia and Marquez, 2006, and Ruckes, 2004).

Finally, the model contributes to the literature on business cycle asymmetries. Existing papers explain growth rate asymmetries with faster learning in booms relative to recessions (Nieuwerburgh and Veldkamp, 2006) or asymmetric technology adoption costs (Jovanovic, 2006). Still other papers focus on the level asymmetries (larger output deviations from trend in recessions than in booms) and put forward different mechanisms such as learning-by-doing in Acemoglu and Scott (1997), credit constraints in Kocherlakota (2000) or capacity constraints in Hansen and Prescott (2005). This paper offers a new mechanism based on higher information asymmetries in financial intermediation in booms.

The remainder of the paper is organized as follows. Section 2 presents an empirical motivation for the theoretical model. To clearly demonstrate the model mechanism and the role of frictions, Section 3 presents a simple two-period model version and solves it analytically. Section 4 sets out the full infinite-horizon DSGE model with long-term loans and risk-averse lenders. All propositions derived in Section 3 can be reproduced analytically in the deterministic steady state of the full model. Section 5 reports the results of the full model with aggregate risk solved using global numerical methods and focuses on the dynamic effects of cyclical variation in asymmetric information. Finally, Section 6 concludes.

2 Empirical motivation

As a motivation to the theoretical model, I present in this section an empirical analysis, which studies the correlation between explicit recourse provided by issuers of ABS and the

quality of asset pools backing those securities over the business cycle.⁴

I use a database of residential mortgage-backed securities (RMBS) in Europe, which contains data on explicit recourse in the form of credit enhancement (financial support to cover losses on underlying mortgages) and delinquency rates on pools of mortgages backing RMBS. I use the realized delinquency rate as a proxy for the inverse of asset quality and, due to aggregation issues, focus on a particular type of explicit recourse: overcollateralization (see below for details).

In this paper I study the hypothesis that recourse can be used in an environment with asymmetric information as a signal of underlying asset quality. For lenders, who securitize high-quality mortgages (with lower risk of future delinquencies), providing protection against losses from defaults is relatively cheap, and therefore, they could use it to signal the quality of RMBS. The **signaling hypothesis** thus implies that lagged recourse should be negatively correlated with the realized delinquency rate of collateral.

However, in practice recourse is also used as a buffer against expected losses. RMBS receive a credit rating that reflects the estimated probability of delinquencies as well as the level of recourse. If estimated delinquencies are high, the issuing lender is asked to provide relatively more recourse as a buffer against higher expected losses to attain a particular rating. The **buffer hypothesis** therefore implies a positive correlation between (lagged) recourse and realized delinquency rates.

Recourse likely serves as both a signal of quality and a buffer against observable risk (expected losses). In this section I try to detect evidence of the signaling hypothesis while controlling for the stage of the business cycle.

2.1 Data description

The Performance Data Services (PDS) database by Moody's contains quarterly data for the period 1998Q2-2013Q2 for RMBS issued in European countries. The dataset contains information on recourse backing RMBS in the form of credit enhancement (credit protection provided to holders of RMBS by the issuer) and on the delinquency rate of mortgages backing those securities.⁵

The delinquency rate is the ratio of the amount of receivables that are 90 or more days past due to the original collateral pool balance. The delinquency rate is available on the

⁴In the model section, I study both explicit and implicit recourse, but for the latter there is limited data. Therefore, this empirical section focuses on explicit recourse.

⁵I would like to thank the European Central Bank for providing me with access to this part of the PDS database. Note that the dataset contains data for a few non-European countries, but this part has either very few observations per country or is incomplete (covers only a short period after the crisis). In Appendix F, Table F.1, I report the data summary statistics.

pool level.⁶ The PDS database contains various types of recourse on tranche-level data. I use the data for overcollateralization, which is the practice when the value of pledged mortgages in the pool exceeds the amount of the RMBS issued against the pool. Excess collateral is used to cover losses from default on mortgages and protects holders of RMBS. The overcollateralization rate in the database is the difference between the principal value of the collateral mortgages and the principal value of the tranches in the deal, normalized by the original collateral principal value. The advantage of this type of recourse is that by definition it is the same for all tranches, i.e., it is available on the deal level. By contrast, other popular forms of recourse are by definition tranche-specific (subordination) or are not always available for all tranches (reserve funds), which complicates the aggregation.

Figure 1. Example of overcollateralization on balance sheet of SPV

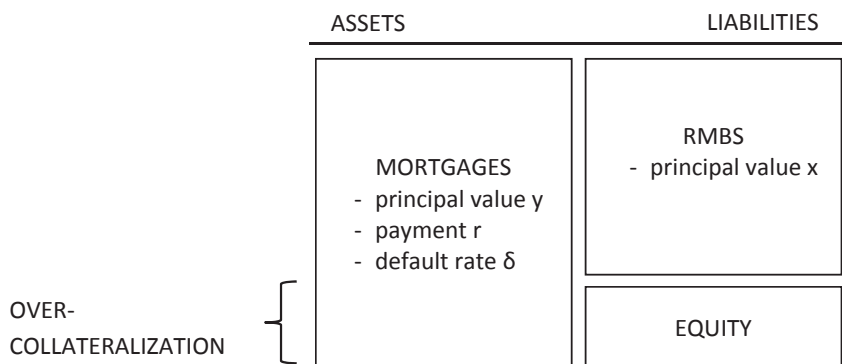


Figure 1 shows a simplified example of overcollateralization. It shows the balance sheet of a Special Purpose Vehicle (SPV) to which mortgages are transferred and which issues RMBS against those mortgages. The principal value of mortgages, y , exceeds the principal value of issued RMBS, x . The difference $y - x$ is the excess collateral position against which a subordinated equity is issued. This equity may be retained by the issuer of mortgages as a way to signal mortgage quality. Any losses from mortgage defaults are first covered by the equity position. Only when the equity is exhausted, will defaults affect returns on RMBS. Suppose that equity is large enough to cover costs of default, $yr\delta$, where r is the loan payment and δ realized default rate. Then RMBS holders receive payment xr and equity holders receive $(y - x)r - yr\delta > 0$. When equity position cannot cover all default losses, then equity holder gets nothing and RMBS holders receive all cash-flows from mortgages $yr(1 - \delta)$, which imply an average payment $yr(1 - \delta)/x$ per security. Let us define an average default rate suffered by the RMBS holder with protection from recourse, δ^G , from

⁶A deal is typically backed by a pool of loans and consists of several tranches. I drop the observations where more pools back the same deal or more deals are backed by the same pool of loans, since I do not have the information needed to do a proper aggregation. Thus I obtain unique deal pool pairs and delinquency available on the deal level.

$xr(1 - \delta^G) \equiv yr(1 - \delta)$. Then it is easy to show that this default rate is lower than the default rate on the underlying mortgages thanks to the recourse protection:

$$\delta^G = \delta - \frac{(y - x)}{x}(1 - \delta) < \delta. \quad (1)$$

Finally, for the measure of the business cycle I use the output gap, obtained by applying the Hodrick-Prescott (HP) filter on the real output data from Eurostat.

2.2 Panel regression results

Regression specification. I run the following regression on the quarterly, deal-level data with fixed effects for deals (indexed by i) and time periods (indexed by t):

$$\begin{aligned} DelinqRate_{i,t} = & \alpha_i + \alpha_t + \beta Overcollat_{i,t-1}^D + \gamma Overcollat_{i,t-1}^D \times D_i^{originated\ in\ boom} \\ & + \iota Z_{i,t} + \varepsilon_{i,t}, \end{aligned} \quad (2)$$

where $DelinqRate_{i,t}$ is the delinquency rate, $Overcollat_{i,t-1}^D$ is the ratio of credit enhancement in the form of overcollateralization to the original pool balance lagged one period and controlled for its potential trend and persistence,⁷ $D_i^{originated\ in\ boom}$ is the dummy variable for deals issued in a boom period of the respective country and $Z_{i,t}$ is the set of control variables.⁸

Regression results. Table 1 shows the results for the five largest European countries by number of observations in the dataset: the United Kingdom (UK), Ireland (IR), Spain (SP), the Netherlands (NL) and Italy (IT). This subset of countries covers 90% of all European observations and represents 85% of all European outstanding RMBS at the end of the data sample in 2013Q2 (AFME, 2013). The remaining European countries have very few observations, which lowers the statistical significance of the results.

For the United Kingdom and Ireland, which together account for 34% of outstanding European RMBS at the end of the data sample in 2013Q2 (AFME, 2013) and 30% of observations in the data,⁹ the results are in line with the signaling hypothesis (coefficient

⁷To avoid a spurious regression problem due to a potential common trend or persistence of the variables, I use lagged delinquency rate $DelinqRate_{i,t-1}$ and $Deal\ age$ (number of quarters since the deal's closing date) as explanatory variables. Moreover, I clear $Overcollat$ from potential trend and persistence in a first-stage regression prior to using it in the main regression (2). Details are reported in Appendix F, where I also show that the results without this first-stage regression step are qualitatively unchanged.

⁸Control variables are $DelinqRate_{i,t-1}$, interaction term of overcollateralization with dummy for boom periods $Overcollat_{i,t-1}^D \times D_{i,t}^{boom}$, $Deal\ age$ and the output gap $Output\ gap \equiv \ln(GDP_{i,t}) - \ln(GDP_{i,t}^{HP})$, where $GDP_{i,t}^{HP}$ is the HP filtered real Gross Domestic Product (GDP , smoothing parameter 1600).

⁹UK market is the largest by size in Europe. UK accounts for 29% of all outstanding European RMBS

of $Overcollat_{i,t-1}^D$ (β) is significantly negative). Moreover, for a subset of deals issued in the boom stage of the business cycle, the signaling hypothesis is rejected (the coefficient of $Overcollat_{i,t-1}^D \times D_i^{originated\ in\ boom}$ (γ) is significantly positive with a value comparable to or exceeding the coefficient of $Overcollat_{i,t-1}^D$).¹⁰

Table 1. Overcollateralization as a signal of deal quality^{ab}

Countries ^c	(1) all 5 countries	(2) UK	(3) IR	(4) SP	(5) NL	(6) IT
$DelinqRate_{i,t-1}$	0.913*** (0.009)	0.869*** (0.010)	0.963*** (0.025)	0.828*** (0.021)	0.897*** (0.016)	0.655*** (0.033)
$Overcoll_{i,t-1}^D$	-0.002 (0.003)	-0.062** (0.027)	-0.550*** (0.184)	-0.003 (0.004)	0.010 (0.011)	0.004 (0.004)
$Overcoll_{i,t-1}^D \times$ $D_i^{origin\ in\ boom}$	0.004 (0.004)	0.073*** (0.028)	0.547*** (0.184)	0.030** (0.015)	0.017 (0.015)	-0.007 (0.005)
$Deal\ age_{i,t}$	-0.038** (0.018)	-0.152*** (0.029)	-0.307** (0.138)	-0.018 (0.026)	0.000 (0.018)	0.135*** (0.047)
$Overcoll_{i,t-1}^D \times$ $D_{i,t}^{boom}$	0.000 (0.004)	0.028 (0.032)	-0.004 (0.003)	0.004 (0.008)	-0.021 (0.019)	0.010** (0.005)
$Output\ gap_{i,t}$	-1.342* (0.793)					
Observations	16,303	3,949	1,346	5,486	3,791	1,731
R-squared	0.879	0.895	0.957	0.734	0.867	0.558
Number of deals	788	190	60	227	195	116

^a Panel data regression with $DelinqRate_{i,t}$ as the dependent variable. I do not report the fixed effects for deals and time periods.

^b Robust standard errors are clustered by deals and reported in parentheses (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

^c Time period is 1998Q2-2013Q2 for the whole sample, 2000Q2-2013Q2 for the UK, 1999Q4-2013Q2 for Ireland, 1998Q3-2013Q2 for Spain, 1998Q2-2013Q2 for the Netherlands and 2001Q1-2013Q2 for Italy.

Over the whole sample of countries, I cannot find support for the signaling hypothesis. This should not be surprising since countries differ in their practices and regulatory treatment of securitization. The Spanish regulator treated all securitized assets as if they would have remained on the issuer's balance sheet (see Acharya and Schnabl, 2010); therefore securitization in Spain was not used to transfer risk, but rather for liquidity reasons (see e.g., Almazan et al., 2015), and recourse did not serve as a signaling tool. In line with this, I find in Spain a positive correlation between lagged overcollateralization and delinquencies for the subset of deals issued in the boom stage of the business cycle. This corresponds to

at the end of the data sample, in 2013Q2 (AFME, 2013), and for 22% of total observations.

¹⁰Moreover, in Appendix F, I report the regression results for the sub-sample of deals issued in the boom stage and the coefficient of $Overcollat_{i,t-1}^D$ is not significantly different from zero, rejecting the signaling hypothesis.

the buffer hypothesis. The fact that I do not detect support for the signaling hypothesis in the Netherlands and Italy does not imply that recourse was not used as a signaling toll, since its simultaneous use as a buffer could prevent this detection.

Signs of the coefficients for control variables are mostly intuitive. They suggest that the delinquency rate is persistent. The negative coefficient of the output gap implies that the delinquency rate is lower in a boom. The coefficient of *Deal age* is significantly negative for the UK and Ireland and positive for Italy. A positive coefficient could suggest an increasing probability of delinquencies over the lifetime of mortgages; a negative coefficient may result from the fact that over time, as some of the loans in the deal come to their maturity, the numerator (delinquent receivables) decreases, while the denominator (the original pool) remains unchanged. In Appendix F, I probe the robustness of these results and show that support for the signaling hypothesis and lower efficiency of signaling for deals issued in a boom are robust to various alternative regression specifications in the case of UK. However, they are somewhat less robust in the case of Ireland, perhaps due to the smaller number of observations.

To conclude, I contribute to the literature that finds support for the signaling hypothesis of explicit credit enhancement in the US (Mandel et al., 2012), by finding support for the signaling hypothesis in the case of the United Kingdom and Ireland. Moreover, I show that this result holds only for loans issued outside of the boom stage of the business cycle. The theoretical sections in this paper replicate the results for the explicit recourse, but more importantly, also for the implicit recourse, for which there is limited data.

3 A simple two-period model

3.1 Environment

The model is based on a simplified framework from Kiyotaki and Moore (2012). The economy is populated by a large number of risk-neutral lenders (indexed by i) who live for two periods $t = 1, 2$ and maximize their continuation value $V(w_i) = \nu w_i$, where w_i is the wealth at the end of period 2.

At the beginning of period 1, all lenders receive an endowment of perishable goods n . An investment shock divides them into three groups: $\pi\mu$ share of lenders can fund high-quality loans with a gross return per unit of lending $r^h \equiv r(1 - \delta^h)$, where r and δ^h are payment and the default probability of high-quality loans, respectively. $\pi(1 - \mu)$ share of lenders can fund low-quality loans with a low gross return per unit of lending $r^l \equiv r(1 - \delta^l)$ in period 2, where $r^h > r^l$ (i.e. $\delta^l > \delta^h$). The remaining lenders have no lending opportunity. For

simplicity, when funding loans, each lender diversifies across many borrowers of the same quality. Therefore, due to a law of large numbers, there is no distribution of realized defaults and respective returns within each category of lenders, and the only idiosyncratic shock is the allocation to a particular type of lending opportunity.

Lenders fund a loan amount x_i at unit marginal costs and issue derivative securities in the same quantity, each backed by loan returns. Issuing lenders can sell a fraction of derivative securities s_i to other lenders (security buyers) for a competitive price q_i and keep the remaining securities on their balance sheet, $a_{i,i} = (1 - s_i)x_i$. There is no scale limit to the loan size, so lenders can use the sale proceeds to increase lending. Therefore, ideally only lenders with high-quality lending opportunity fund loans and sell securities to remaining lenders.

However, there are two frictions in the financial intermediation. First, there is a “skin in the game” constraint (hereafter SGC): issuing lenders can sell at most a fraction $\theta \in [0, 1]$ of their derivative securities. Second, loan returns are private information.

Issuing lenders are competitive, so they take price q_i as given and sell securities for any price that covers unit funding costs, $q_i \geq 1$. I refer to derivative securities backed by high- and low-quality loans as high- and low-quality securities and to the creation and sale of securities as securitization. Lenders can also buy securities issued by other lenders (indexed by j): $\{a_{i,j}\}$ at prices $\{q_j\}$ for all $j \neq i$.

Security design with recourse. Lenders can alter the security payoff using a recourse in the form of a guaranteed minimum return $r_i^G \equiv r(1 - \delta_i^G)$ on securities, where δ_i^G is the guaranteed maximum borrower default cost suffered by security buyers after recourse. This means that lenders promise to pay to security buyers any positive difference between the guaranteed return r_i^G and the loan return $r_i \in \{r^h, r^l\}$, resulting in a promised payment:

$$g_i^G \equiv \max \{r_i^G - r_i, 0\} = \max \{(\delta_i - \delta_i^G)r, 0\}$$

per unit of security. In other words, lenders promise to cover default losses $\max \{(\delta_i - \delta_i^G)r, 0\}$, which leaves security buyers only with default losses of $\min \{\delta, \delta^G\}r$. The recourse can be either explicit, r_i^{EG} , or implicit, r_i^{IG} .

Explicit recourse is legally binding but carrying additional regulatory costs g_i^R , which are proportional to explicitly promised recourse payment. Due to asymmetric information, size of the recourse payment may not be observed, so for prudential reasons regulatory costs are set as a τ fraction of the maximum possible provided recourse payment:

$$g_i^R = \tau E^B \max g_i^{EG} = \tau \max \{r_i^{EG} - E^B \min r_i, 0\},$$

where E^B is the expectation conditional on the information set of security buyers. Therefore, when information about underlying loan return is revealed in equilibrium $E^B \min r_i = r_i$, otherwise $E^B \min r_i = r^l$ for all i .

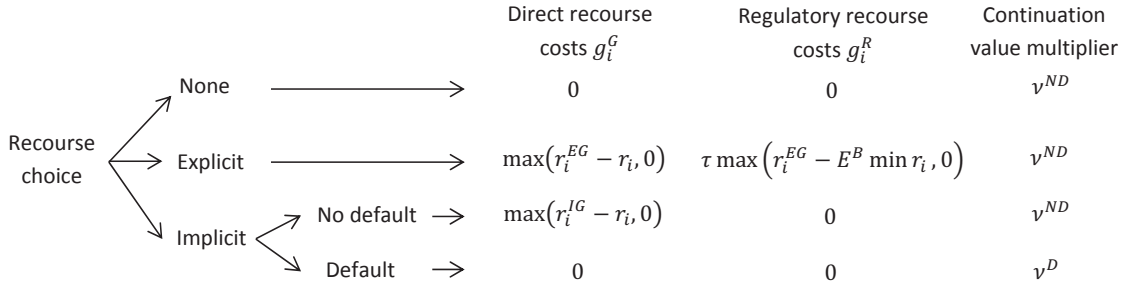
Implicit recourse is non-contractual and has a default option. Default on implicit recourse, $\chi_i \in \{0, 1\}$ is 0 when lender defaults otherwise 1, may negatively affect the lender's continuation value multiplier:

$$\nu |_{\chi_i=1} \equiv \nu^{ND} \geq \nu |_{\chi_i=0} \equiv \nu^D.$$

The negative effect of defaults is an increasing function in the lender's profits from the security sale and is zero when these profits are zero: $\nu^{ND} - \nu^D = f(\pi_{sale})$, $f'(\cdot) > 0$ and $f(0) = 0$, where $\pi_{sale} = w_i - w_i |_{s_i=0}$.¹¹ Figure 2 summarizes the distinct recourse options and their implications. Total costs of both explicit and implicit recourse per unit of sold securities g_i^T to the issuing lender are given by:

$$g_i^T = \max \{g_i^{EG}, \chi_i g_i^{IG}\} + g_i^R. \quad (3)$$

Figure 2. Recourse options



Issuing lenders have incentives to provide recourse because it can increase the price for which securities are sold for two reasons. First, since security buyers receive in period 2 a return augmented by the recourse, $\hat{r}_i = \max\{r_i, r_i^{EG}, \chi_i r_i^{IG}\}$, they are willing to pay a higher price for a recourse exceeding underlying loan return. Second, based on the recourse, buyers update their beliefs in period 1 about the underlying loan quality. Since recourse is more expensive (g_i^T is higher) for issuers with low-quality loans, recourse can signal underlying loan quality. Let $\varphi_j(b_{j,1}) \in [0, 1]$ denote the posterior buyers' belief in period 1 that the security sold by lender j is of high quality, where b_j is the set of publicly observable control variables of the selling lender j . That is, $b_{j,1} = \{r_j^{EG}, r_j^{IG}, s_j\}$ in period 1, and $b_{j,2} = \{\hat{r}_j, \chi_j\}$

¹¹In the full infinite-horizon model in Section 4, I endogenize the effect of default on the lender's value function by assuming that default triggers a punishment in the form of an inability to issue new securities.

in period 2.

Explicit recourse in the model is analogous to the practice of issuers of asset-backed securities, who cover part of the losses from default on sold loans that back the securities. Methods used are, for instance, overcollateralization (provision of more underlying loans than the value of issued ABS to absorb potential losses and protect ABS holders - see equation (1) for an explicit link between default costs suffered by security buyers in the model δ^G and an overcollateralization position in Section 2). Another method is the creation of tranches ordered by default risk and retention of the most risky (junior) tranche. In both cases issuers cover a part of the default costs on loans sold to buyers, similarly as in the model. Higher exogenous costs of explicit recourse reflect the additional regulatory costs that issuers have to face in reality and capture the main advantage of implicit recourse, which is regulatory arbitrage.

The timing of shocks and the choice of a lender's controls in both periods are shown in Figure 3. The lender's problem can be summarized as follows: each lender chooses $\{x_i, s_i, r_i^{EG}, r_i^{IG}, \chi_i, \{a_{i,j}\}_j\}$ to maximize its continuation value

$$\max EV(w_i) = E\nu w_i \quad (4)$$

subject to the SGC and budget constraints:

$$s_i \leq \theta, \quad (5)$$

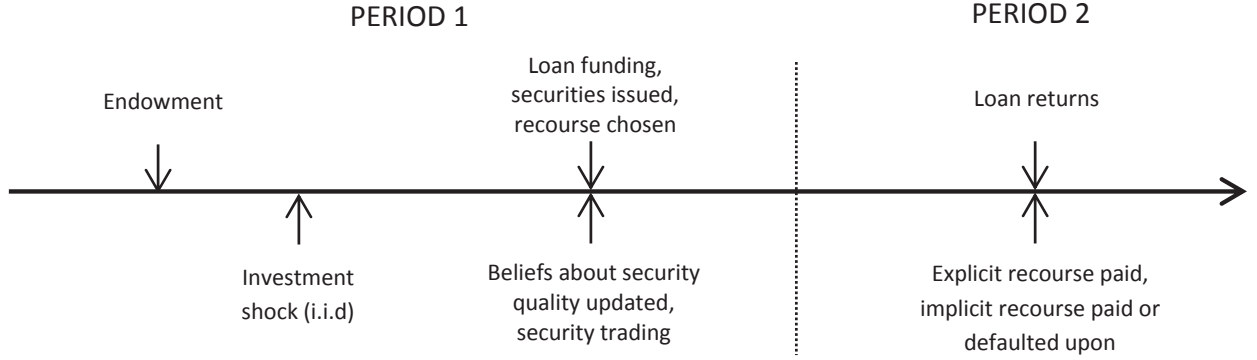
$$x_i + \sum_{j \neq i} a_{i,j} q_j = n + s_i x_i q_i, \quad (6)$$

$$w_i = \sum_{j \neq i} a_{i,j} \hat{r}_j + a_{i,i} r_i - g_i^T s_i x_i, \quad (7)$$

where $q_i = q(r_i^{EG}, r_i^{IG}, \varphi_i)$ and g_i^T is given by (3). The period 1 budget constraint (6) states that a lender's endowment, together with the market value of sold securities, $s_i x_i q_i$, must equal the costs of lending, $x_i \equiv s_i x_i + a_{i,i}$, and costs of buying derivative securities from other lenders, $\sum_{j \neq i} a_{i,j} q_j$. The period 2 budget constraint (7) states that a lender's wealth at the end of period 2, w_i , is comprised of security returns augmented by the recourse received from other lenders, after deducting the costs of recourse provided by the lender, $g_i^T s_i x_i$.

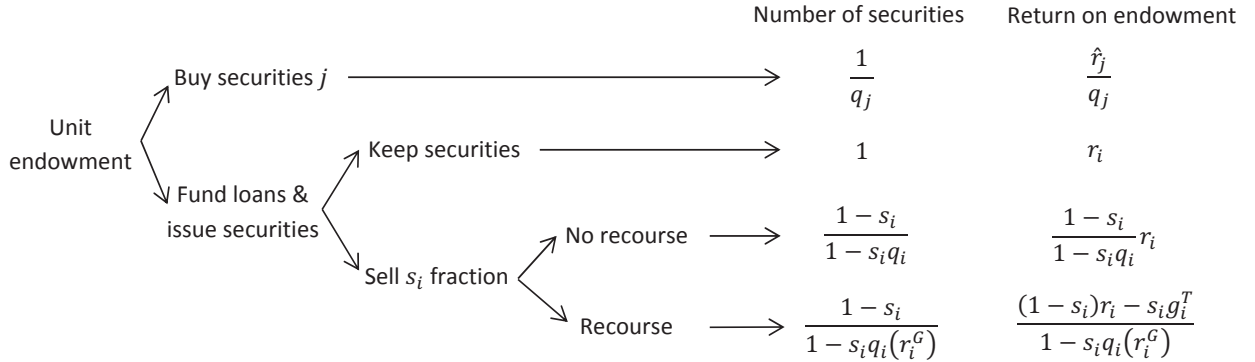
Figure 4 summarizes lenders' options for allocation of their endowment. Note in particular that if lenders decide to issue and sell securities, then they can use profits from securitization, $(q_i - 1)s_i x_i$, to fund new loans and thus lever up their return on endowment. Return takes the form $(1 - s_i)r_i/(1 - s_i q_i)$ because lenders retain $(1 - s_i)$ of their lending but need to pay from their endowment only $(1 - s_i q_i)$ per unit of lending since they sell s_i share of loans

Figure 3. Timing of shocks and choice of a lender's controls within each period



for price q_i . If q_i exceeds unit lending costs then securitization increases return of issuing lenders, otherwise it has no effect on them. Notice also that recourse (explicit or implicit) can on the one hand reduce the return due to costs of honoring recourse that exceeds loan returns, but on the other hand recourse can increase the security price, and therefore increase the leverage from securitization profits.

Figure 4. Summary of investment options for a unit of endowment



Market clearing. Finally, the model is closed with market clearing conditions. The goods market clears in period 1 when all endowment $N \equiv \sum_i n$ is invested in loans

$$\sum_i x_i = N, \quad (8)$$

and in period 2 when all loan returns after deducting regulatory costs of explicit recourse constitute the aggregate wealth of lenders:

$$W \equiv \sum_i w = \sum_i (x_i r_i - g_i^R). \quad (9)$$

Market clearing condition (8) determines the average price for which securities are traded. Relative prices for securities issued by different lenders are determined by the indifference conditions of security buyers that equalize the expected returns from buying traded securities, i.e., expected security return conditional on the information set of buyers $E^B(\hat{r}_j)$ per security price paid q_j is equalized for any traded pairs of securities $\{j, j'\}$:

$$E^B(\hat{r}_j/q_j) = E^B(\hat{r}_{j'}/q_{j'}) \quad \forall j, j'. \quad (10)$$

3.2 Equilibrium definitions and refinement

Formally, the actions and objectives of lenders define an extensive-form game of incomplete information, which may have multiple perfect Bayesian equilibria (PBE) defined below.

Definition 1. *A competitive PBE consists of prices $q_i = q(r_i^{EG}, r_i^{IG}, \varphi_i)$ and individual strategies $\{x_i, \{a_{i,j}\}_j, r_i^{EG}, r_i^{IG}, \chi_i\}$ such that:*

- a. *taking price functions $q(r_i^{EG}, r_i^{IG}, \varphi_i)$ as given, individual strategies of loan funding x_i , securities retained $a_{i,i}$ and bought $\{a_{i,j}\}_{j \neq i}$, recourse provision r_i^{EG}, r_i^{IG} in period 1 and strategy of implicit recourse default χ_i in period 2:*
 - *maximize lenders' continuation value $V(w_i)$ subject to the SGC (5) and budget constraints (6-7), and*
 - *are sequentially rational given buying lenders' beliefs about the quality of securities sold by lenders j : $\varphi_j(r_i^{EG}, r_i^{IG}, a_{i,i})$;*
- b. *prices $\{q_i\}$ clear both the goods (8 and 9) and securities markets (10);*
- c. *lenders update their beliefs about underlying loan quality φ_j using Bayes' rule on the equilibrium path.*

Any equilibrium is either pooling or separating. In a pooling equilibrium, lenders with high-quality loans and at least some lenders with low-quality loans optimally choose the same level of controls observed by all other lenders $b_{i,1}$. Therefore, both high- and low-quality securities are sold in the market and buyers cannot distinguish between them. In a separating equilibrium, lenders with high- and low-quality loans optimally select different observable controls, and therefore, buyers can identify the quality of loans backing each security.

I use the **intuitive criterion** (Cho and Kreps, 1987) as a refinement to eliminate dominated equilibria with unreasonable out-of-equilibrium beliefs. Consider an equilibrium in

which lenders have value functions V^{h*} and V^{l*} if they sell high- and low-quality securities, respectively. This equilibrium satisfies the intuitive criterion if there does not exist a choice of a lender's observable control variables in period 1 b'_1 such that: (a) lenders selling high-quality securities prefer to choose b'_1 : $V |_{\varphi=1, b_1=b'_1} > V^{h*}$ and (b) lenders selling low-quality securities do not choose b'_1 even when it is considered as a signal of high-quality: $V |_{\varphi=1, b_1=b'_1} < V^{l*}$. If such an observable control b'_1 exists, then uninformed buyers should believe that only lenders selling high-quality securities would choose b'_1 , which by (a) would represent a profitable deviation for lenders selling high-quality securities and cause this equilibrium (with value functions V^{h*} and V^{l*}) to fail the intuitive criterion.

The implicit recourse can be enforced in a reputation equilibrium, where originating lenders want to keep their reputation of honoring recourse. In such an equilibrium, losing this reputation by defaulting on the implicit recourse must lower the lender's continuation value: $\nu^{ND} > \nu^D$. I call an implicit recourse exceeding the underlying loan return credible, if the originating lender i honors the recourse, i.e., when a non-default condition is satisfied:

$$EV_i |_{\chi_i=1} \geq EV_i |_{\chi_i=0} . \quad (11)$$

Definition 2. *In a **reputation equilibrium** lenders provide and honor an implicit recourse exceeding the underlying loan return.*

Since at $t = 2$ security holders observe only the augmented return on loans,¹² when the recourse exceeds return of both loan types ($\hat{r}_i > r^h > r^l$), then in such a pooling equilibrium the loan quality never becomes public information. Unlike in the case of observable default on implicit recourse, the continuation value of lenders who sell low-quality securities is not negatively affected by the fact that they are “lying” about loan quality.

3.3 Equilibrium characterization

To show the effects of frictions in financial intermediation, I first solve the model without frictions, and then successively introduce asymmetric information and a binding SGC. First, I show that without binding SGC only high-quality loans are funded, even in the presence of asymmetric information, i.e., the allocation of endowment is first-best. Second, a binding SGC restricts the security supply and makes securitization profitable, which in turn makes funding of low-quality loans under asymmetric information attractive, and may result in a pooling equilibrium. Finally, I show that the provision of recourse, both explicit and implicit,

¹²This assumption can be mainly justified in the case of implicit recourse, which is used in reality as a means of regulatory arbitrage. Therefore, issuers of ABS prefer to provide recourse in ways that are hard to detect by the regulator, so they would hide the underlying loan return r_i .

increases the parameter subspace where a separating equilibrium exists, and thereby improves resource allocation. But pooling equilibria still exist for sufficiently low dispersion between returns on high- and low-quality loans. Therefore, the dynamic model in the next section with countercyclical dispersion in loan returns features switching between pooling equilibria in booms (low return dispersion) and separating in bust (high return dispersion).

3.3.1 Cases without binding SGC: first-best

No financial frictions. If there is no binding SGC and loan quality is public information, then only high-quality loans are funded, securitized into high-quality securities and sold to lenders without high-quality lending opportunity.

Since the lenders issuing new securities are competitive price-takers in the market and the SGC does not restrict security supply, then for markets to clear, issuing lenders have to be indifferent about creation and sale of securities. That implies that the price of high-quality securities equals marginal lending costs: $q_i \equiv q^h = 1$. Since all endowment is used in period 1 to fund high-quality loans, the wealth of each lender ($w_i = n_i r^h \forall i$) as well as the aggregate wealth in period 2 ($W = N r^h$) is at the highest feasible level; therefore, the model solution is first-best.

The following claim characterizes the choice of recourse and implies that since securitization brings zero profits for the issuing lender (revenue from security sale equals the lending costs, $q_i = 1$), no recourse is provided in equilibrium.

Claim 1. *Under symmetric information, due to competition,*

- *explicit recourse is provided if $q^h \geq 1 + \tau$,*
- *credible implicit recourse is provided if the non-default condition (11) is satisfied, which implies a necessary condition $q^h > 1$.*

Proof. See Appendix A.1. ■

Intuition for Claim 1 is the following. Explicit recourse is provided as long as the marginal benefits of recourse, q^h , exceed marginal recourse costs, $1 + \tau$. For implicit recourse to be credible, securitization needs to be profitable, therefore $q^h > 1$.

Introducing asymmetric information. Asymmetric information allows lenders with low-quality loans to mimic those with high-quality loans. In a pooling equilibrium, they can sell low-quality securities at a market price $q_i \equiv q$ (to be determined), which reflects the average quality of funded loans and exceeds the value of low-quality securities. A separating

equilibrium exists only if lenders with low-quality loans prefer buying high-quality securities to mimicking lenders with high-quality loans:

$$V_i |_{\text{buying securities}} > V_i |_{\text{mimicking}}, \quad (12)$$

where mimicking requires a lender to fund and securitize loans and sell derivative securities with the same observable controls $(b_{i,1})$ as those chosen by lenders with high-quality loans. Again, because of competition, $q^h = 1$, securitization is not profitable; therefore no recourse is provided, and condition (12) can be written as $\nu n_i r^h > \nu n_i r^l$, which collapses to $r^h > r^l$ and is always satisfied by assumption. Therefore, only high-quality loans are funded and information about security quality is revealed in equilibrium. This insight leads to the following proposition.

Proposition 1. *If the SGC does not bind, then the endowment allocation in equilibrium is first-best, even with asymmetric information friction.*

3.3.2 Cases with binding SGC

The SGC binds when it restricts lenders with high-quality loans. In this case, lenders with high-quality loans sell securities backed by θ -share of their loans, $s_i = \theta$, and keep the remaining loans, $a_{i,i} = (1 - \theta) x_i$. They use all resources to fund lending, i.e. they do not buy securities issued by other lenders, $\sum_{j \neq i} a_{i,j} q_j = 0$. Therefore, their period 1 budget constraint (6) becomes

$$x_i = \frac{n}{(1 - \theta q_i)}. \quad (13)$$

I guess and verify that all lenders with high-quality loans behave symmetrically and, as a result, securities issued by them are priced equally, $q_i = q$. Since the individual investment function (13) is linear in endowment and the investment shock is i.i.d., I can aggregate them to obtain $\sum_i x_i = \pi \mu N / (1 - \theta q)$. This equation in combination with the goods market clearing condition (8), $\sum_i x_i = N$, gives an expression for the equilibrium price:

$$q = \frac{1 - \pi \mu}{\theta} \quad (14)$$

and leads to the next proposition.

Proposition 2. *If the “skin in the game” is sufficiently large to satisfy*

$$1 - \theta > \pi \mu, \quad (15)$$

then the SGC binds and the price of high-quality securities exceeds lending costs, $q > 1$.

Condition (15) implies that if the share of securities that need to remain on the balance sheets of lenders with high-quality loans, $1 - \theta$, exceeds their share of endowment $\pi\mu$, then the security supply is restricted. To clear the market, the price must exceed the marginal costs of lending. This makes securitization profitable. Indeed, the budget constraint (13) can be rewritten as

$$a_{i,i}q^S = n, \text{ where } q^S \equiv \frac{1 - \theta q}{1 - \theta} < 1. \quad (16)$$

Issuing lenders acquire securities that remain on their balance sheets at the effective price q^S , because issuing lenders end up owning a fraction $(1 - \theta)$ of loans issued but need to pay from their endowment only $(1 - \theta q)$ per unit of lending since they sell θ -share of loans for price q . As a result, issuing lenders need $(1 - \theta q)/(1 - \theta)$ to acquire one unit of security. Their return on endowment is then levered with the profit from securitization: $\frac{r^h}{q^S} = \frac{1 - \theta}{1 - \theta q} r^h > r^h$, and exceeds the return on the endowment of lenders without a high-quality lending opportunity, $\frac{r^h}{q} < r^h$.

No recourse. For the sake of exposition, I first show the equilibrium without recourse and then I compare it to cases with explicit and implicit recourse, respectively. Therefore, first suppose that explicit recourse technology is not available, $r_i^{EG} = 0 \forall i$, and default on implicit recourse does not affect continuation value, $\nu(\chi_i) = \nu \forall \chi_i$, which renders any implicit recourse non-credible.

Claim 2. *Suppose condition (15) in Proposition 2 is satisfied and neither explicit nor credible implicit recourse are available. Then the equilibrium is separating if*

$$\frac{r^h}{q^h} > \frac{r^l}{q^S}, \quad (17)$$

or, equivalently, if the return dispersion satisfies:

$$\frac{r^h}{r^l} > \frac{q^h}{q^S} = \frac{(1 - \theta)(1 - \pi\mu)}{\pi\mu\theta}, \quad (18)$$

where q^h is the price of a high-quality security without recourse, $q^h = q = (1 - \pi\mu)/\theta$.

Proof. See Appendix A.2, which also characterizes the equilibrium. ■

The non-mimicking condition (17) for lenders with low-quality loans implies that their return from buying securities in the market exceeds their return from funding low-quality loans levered with profits from securitizing loans and passing them for high-quality (i.e., acquiring low-quality securities at a lower effective price $q^S = (1 - \theta q^h)/(1 - \theta) < 1$). Since condition (15) is satisfied, the right-hand side (RHS) of (18) exceeds one, and therefore

a pooling equilibrium exists for small return dispersions. The non-mimicking condition (18) implies that the return dispersion has to be higher for tighter financial intermediation frictions (low θ , μ and π). These frictions restrict the security supply and increase the equilibrium market price, making mimicking more attractive.

Particularly interesting is the effect of the maximum fraction of securities for sale θ on the non-mimicking condition. It can be decomposed into a direct and an indirect (general equilibrium) effect. The direct effect of larger θ increases the RHS of (18) and makes a separating equilibrium less likely, because the skin in the game, which is more costly for lenders with low-quality loans, is reduced. The indirect effect of larger θ is lower equilibrium price, lower RHS of (18) and higher likelihood of a separating equilibrium. This is because a lower price makes securitization less profitable. The indirect general equilibrium effect dominates:

$$d\left(\frac{q^h}{q^S}\right)/d\theta = \frac{1}{(1-\theta q^h)^2} \left(\overbrace{q^h(q^h-1)}^{\text{direct effect (+)}} + \overbrace{(1-\theta)\frac{dq^h}{d\theta}}^{\text{indirect effect (-)}} \right) < 0. \quad (19)$$

This result also implies that lenders with high-quality loans cannot deviate from the pooling equilibrium to a separating equilibrium by keeping higher than the minimum required skin in the game (selling lower than the maximum investment share $s_i < \theta$).¹³ In partial equilibrium, a lower s_i might signal security quality because it is more costly for lenders with low-quality loans, but the indirect effect dominates in this general equilibrium model.

Claim 3. *Lowering the skin in the game (higher s_i) cannot signal loan type in the equilibrium.*

Explicit recourse provided. Recourse increases the security payoff and under asymmetric information it can serve as a signal of security quality, because recourse provision is more costly for lenders selling low-quality securities than for lenders selling high-quality securities. The update of beliefs and the intuitive criterion refinement determine the equilibrium.

Claim 4. *Suppose condition (15) in Proposition 2 is satisfied and only the explicit recourse is available. Then the equilibrium that satisfies the intuitive criterion is separating if*

$$\frac{r^h}{q^h} > \frac{r^l - \frac{\theta}{1-\theta} [\max\{r^{EG} - r^l, 0\} + \tau \max\{r^{EG} - r^h, 0\}]}{q^S}, \quad (20)$$

which translates into a necessary condition for the return dispersion:

$$\frac{r^h}{r^l} > \frac{(1+\tau)(1-\pi\mu)}{(1+\tau)(1-\pi\mu) - \tau\pi\mu(1-\pi\mu-\theta)}, \quad (21)$$

¹³In reality such behavior is sometimes referred to as “vertical risk retention.”

where $q^h = q \frac{r^h}{\max\{r^{EG}, r^h\}}$.

Proof. See Appendix A.3. ■

Comparing the non-mimicking condition (20) with recourse to the one without recourse (17), we find that costs of explicit recourse (proportional to the promised payment $r^{EG} - r^l$, the regulatory costs $\tau(r^{EG} - r^h)$ given that $\varphi = 1$, θ fraction of sold securities per $(1 - \theta)$ fraction of retained securities) reduce the return from mimicking (RHS of (20)). Provision of recourse does not affect the equilibrium price for which securities with recourse are sold, $q_i \equiv q$, which depends only on the parameters that restrict the security supply $q = (1 - \pi\mu)/\theta$ (see 14), and therefore neither affects the effective price at which issuing lenders acquire securities, $q^S = \pi\mu/(1 - \theta)$. Recourse has no effect on q^h unless it exceeds the return on high quality loans, in which case it reduces q^h . As a result, it can increase the return on buying securities, LHS of (20). To sum up, recourse increases securitization costs, which erodes the returns of all issuing lenders because they are competitive price-takers. But especially returns of lenders who issue low-quality securities are reduced. Moreover, recourse can increase the return from buying loans. Therefore, recourse disincentivizes mimicking by lenders with low-quality loans. Indeed, the condition (20) is satisfied on a larger parameter subspace than condition (17).

The necessary condition for separation (21) is obtained from equation (20) by substituting the equilibrium prices and the maximum recourse that the lenders with high-quality loans are willing to provide in order to separate. Such level of recourse equalizes the return from selling securities with recourse considered as high-quality with the return from being considered as a seller of low-quality securities (in this case lenders either sell securities without recourse or keep all loans on their balance sheet):

$$\frac{(1 - \theta)r^h - \theta(r^{EG} - r^h)(1 + \tau)}{(1 - \theta q)} = r^h \max \left\{ 1, \frac{1 - \theta}{1 - \theta q^l} \right\}. \quad (22)$$

The RHS of condition (21) exceeds one, because $\tau > 0$ and condition (15) holds. Therefore, a pooling equilibrium exists for small return dispersions. The RHS of (21) collapses to 1 for $\tau = 0$, which implies that in the absence of regulatory costs equilibrium would be always separating. Higher regulatory costs of explicit recourse increase the RHS of (21), increase the probability of a pooling equilibrium, and therefore worsen the resource allocation. Proposition 3 summarizes.

Proposition 3. *Provision of an explicit recourse increases the parameter space for which a separating equilibrium exists, and thereby improves the aggregate allocation of resources. However, as long as $\tau > 0$, it does not eliminate all the friction-related inefficiencies as pool-*

ing equilibria still exist. Increasing explicit recourse costs τ worsens the resource allocation.

Proof. See Appendix A.3. ■

Credible implicit recourse provided. A credible implicit recourse can be provided in a reputation equilibrium, and serve as a signal of security quality. The equilibrium is again refined using the intuitive criterion.

Claim 5. *Suppose condition (15) in Proposition 2 is satisfied and explicit recourse is not available. Then the equilibrium is separating if*

$$\frac{r^h}{q^h} \nu^{ND} > \max \left\{ \frac{r^l - \frac{\theta}{1-\theta} \max \{ r^{IG} - r^l, 0 \}}{q^S} \nu^{ND}, \frac{r^l}{q^S} \nu^D \right\}, \quad (23)$$

or, equivalently, if the return dispersion satisfies:

$$\frac{r^h}{r^l} > \frac{q^h \nu^D}{q^S \nu^{ND}} = \frac{(1 - \theta P) q^h}{1 - \theta P q^h} = \frac{(1 - \theta P) (1 - \pi \mu)}{P \pi \mu \theta}, \quad (24)$$

where $P \equiv r_i^{IG}/r^h > 1$ for all i is the price premium for recourse and $q^h = q/P$ is the price of a high-quality security without recourse.

Proof. See Appendix A.4, which also characterizes the equilibrium. ■

The non-mimicking condition (23) states that the return from buying securities exceeds the return from funding and securitizing low-quality loans with implicit recourse and then either defaulting or honoring the recourse. Comparing this non-mimicking condition with recourse to the one without recourse (17), we find that recourse lowers the return from mimicking, RHS of (23), both when recourse is honored because of recourse costs (proportional to $r^{IG} - r^l$) and when recourse is defaulted upon because of lower continuation value ν^D . Similar to the case with explicit recourse, effective price at which issuing lenders acquire securities, q^S , is not affected by recourse, but price of high-quality security without recourse q^h is lower because $r^{IG} > r^h$. Lower price increases the return from buying loans. Therefore, recourse provision disincentivizes mimicking by lenders with low-quality loans. And, indeed, the condition (23) is satisfied on a larger parameter subspace than condition (17).

Condition (24) is derived from (23) after substituting for prices, continuation values and recourse. Due to competition, the equilibrium recourse is the highest credible recourse that satisfies the non-default condition (11) for lenders selling high-quality securities, i.e., condition (11) is satisfied with equality:

$$\frac{r^h - \frac{\theta}{1-\theta} (r^{IG} - r^h)}{q^S} \nu^{ND} = \frac{r^h}{q^S} \nu^D, \quad (25)$$

which simplifies to $(1 - \theta P)\nu^{ND} = (1 - \theta)\nu^D$. This also implies that any mimicking lender with low-quality loans, for whom honoring recourse is more expensive, would prefer to default on the recourse.

Credible implicit recourse can be provided only if the default is costly, $\nu^{ND} > \nu^D$, which takes place only when the security sale is profitable, $q^h > 1$. This observation implies that the RHS of (24) exceeds one, $(1 - \theta P)q^h > 1 - \theta Pq^h$ for $q^h > 1$, so a pooling equilibrium exists for small return dispersions that do not satisfy (24). Proposition 4 summarizes.

Proposition 4. *Provision of implicit recourse increases the parameter subspace for which a separating equilibrium exists, and thereby improves aggregate resource allocation. However, it does not eliminate all the friction-related inefficiencies as pooling equilibria still exist.*

To sum up, I have shown in this section that the provision of both explicit and implicit recourse can signal security quality and achieve a separating equilibrium. But the equilibrium remains pooling for low dispersion of loan returns. The full model in the next two sections features aggregate productivity shocks and a countercyclical dispersion of returns, which both result in the switching between a pooling equilibrium in booms and a separating equilibrium in recessions. Dynamic implications of this variation in asymmetric information are analyzed.

4 Full infinite-horizon model

4.1 Environment

The full model is populated by a continuum of risk averse, infinitely-lived lenders. Every period, lenders consume part of the wealth and use the rest to fund long term loans. I show that the main results derived in the two-period model hold in this more general model by re-deriving analytically the main propositions of the previous section for the model's deterministic steady state. The full stochastic model is solved using global numerical solution methods and its dynamic properties are shown in Section 5.

4.1.1 Loan payoffs over the cycle

As in the two-period model, lenders are divided into three groups by an i.i.d. shock κ_t : $(1 - \pi)$ fraction of lenders have no new lending opportunities, $\pi\mu$ fraction of lenders (subset \mathcal{H}_t) can fund high-quality loans with a high gross return $r_t^h = r_t(1 - \delta_t^h)$, and $\pi(1 - \mu)$ share of lenders (subset \mathcal{L}_t) can fund low-quality loans with a low gross return $r_t^l = r_t(1 - \delta_t^l)$, where $r_t^h > r_t^l$.

Loans are awarded to borrowers. Following Gertler and Kiyotaki (2010) I assume that borrowers use loans to run a project and are able to offer a perfectly state-contingent debt, and lenders have all the bargaining power and extract the entire project profit/income from borrowers. Borrowers default when the project fails with probability δ_t^h and δ_t^l for high- and low-quality borrowers, respectively. In the absence of default, loans return $r_t = A_t K_t^{\alpha-1}$. A_t is the aggregate TFP and K_t is the aggregate holdings of high- and low-quality capital, H_t and L_t , respectively: $K_t = H_t + L_t$. Economy output Y_t is given by $Y_t = r_t^h H_t + r_t^l L_t = \left(A_t^h \frac{H_t}{K_t} + A_t^l \frac{L_t}{K_t} \right) K_t^\alpha$, where $A_t^h \equiv (1 - \delta_t^h) A_t$ and $A_t^l \equiv (1 - \delta_t^l) A_t$. Note that there are decreasing returns to scale in lending (investment) on the aggregate level. But, as in Kiyotaki and Moore (2012), lenders are small and face constant returns to scale, i.e., they take r_t^h and r_t^l as given.¹⁴ Loans are long term: each period $(1 - \lambda)$ fraction of loans amortize. Underlying projects depreciate at the same rate as loans amortize.

Countercyclical dispersion. The relative difference in gross returns from high- and low-quality loans is countercyclical:

$$\frac{\partial}{\partial A_t} \frac{r_t^h - r_t^l}{r_t^l} < 0. \quad (26)$$

In other words, a return dispersion shock is negatively correlated with the productivity shock. In the context of business loans this assumption is inspired by the empirical evidence in Bloom (2009) and Bloom et al. (2012) on countercyclical cross-sectional variance in the TFP of U.S. firms.¹⁵ In the context of household credit, this assumption is inspired by the countercyclical income risk literature, in particular by the evidence in Guvenen et al. (2014) that left-skewness of income shocks is strongly countercyclical. This means that while in recessions an average household (or firm) has a slightly lower income (productivity), a subset of households (firms) have significantly lower incomes (productivities). Loans to the latter households (firms) are more prone to delinquencies, which implies a countercyclical loan return dispersion.

¹⁴Kiyotaki and Moore (2012) obtain this result endogenously by including labor in the project production function and requiring a competitive wage to be paid to workers.

¹⁵Motivated by the empirical evidence, Bloom (2009) and Bloom et al. (2012) construct models that assume time-varying second moments of idiosyncratic TFP shocks and show that a higher variance can cause a recession. This can be reinterpreted in a simpler setting as a negative correlation between productivity and dispersion shocks.

4.1.2 Lenders' problem

Each lender (indexed by i) maximizes its utility from consumption.¹⁶ A lender's wealth at the beginning of period $w_{i,t}$ consists of security returns and the market value of the non-amortized fraction λ of securities, reduced by the costs of explicit and implicit recourse promised in the preceding period. This wealth is used to consume $c_{i,t}$, to invest $x_{i,t}$, to keep non-amortized securities and to acquire new securities. When a loan is funded, derivative securities backed by loan returns are issued. Issuing lenders sell $s_{i,t}x_{i,t}$ of these securities for the market price $q_{i,t}^P$ and can use explicit ($r_{i,t+1}^{EG}$) and implicit recourse ($r_{i,t+1}^{IG}$) to alter the payoff of derivative securities.¹⁷ Explicit recourse carries additional regulatory costs $g_{i,t+1}^R = \tau E^B \max g_{i,t+1}^{ER}$ and implicit recourse can be defaulted upon ($\chi_{i,t+1} = 0$). For simplicity, regulatory costs are returned to issuing lenders in lump-sum transfers per security sold $y_{i,t+1} = g_{i,t+1}^R$, so lenders ignore the effect of explicit recourse choice on transfers. Security buyers receive a return augmented by the recourse: $\hat{r}_{i,t+1} = \max\{r_{i,t+1}, r_{i,t+1}^{EG}, \chi_{i,t+1}r_{i,t+1}^{IG}\}$. Each buyer can observe only the following issuing lender j controls $b_{j,t} = \{r_{j,u+1}^{EG}, r_{j,u+1}^{IG}, s_{j,u}, \hat{r}_{j,u}\} \forall u \leq t$, based on which they update beliefs about the quality of securities sold $\varphi_{j,t}(b_{j,t})$. Total recourse costs to the issuing lender per unit of sold security $g_{i,t+1}^T$ are given by:

$$g_{i,t+1}^T = \max\{g_{i,t+1}^{EG}, \chi_{i,t+1}g_{i,t+1}^{IG}\} + g_{i,t+1}^R.$$

To keep the model tractable, the information about the issuer of a particular security is available only for one period after security issuance.¹⁸ This implies that explicit and credible implicit recourse can be provided only for one period, because no recourse exceeding the project return will be provided when security holders cannot identify the issuer. As a result of this assumption, there are three types of securities in every period t :

- Securities issued in the current period t : $a_{i,j,t}^P$ traded for $q_{j,t}^P$,
- Securities issued in the previous period $t - 1$: $a_{i,j,t}^S$ traded for $q_{j,t}^S$,
- "Old" securities issued in periods prior to $t - 1$, which have informative cash-flows due to the absence of recourse, and therefore, collapse into "old" high- and "old" low-quality securities: $h_{i,t}^O$ and $l_{i,t}^O$ traded for q_t^h and q_t^l , respectively.

¹⁶Except for securities and their prices, the notation remains the same as in the two-period model (Section 3).

¹⁷This implies a promised payment to security buyers of $q^{EG} = \max\{r_{i,t+1}^{EG} - r_{i,t+1}, 0\}$ or $q^{IG} = \max\{r_{i,t+1}^{IG} - r_{i,t+1}, 0\}$ per security sold, respectively.

¹⁸In a related paper, Kuncl (2016) relaxes this assumption, features infinite-horizon implicit recourse and replicates the main qualitative results of this paper.

Securities issued in periods t and $t - 1$ have known issuers but, due to the asymmetry of information, their quality is not known unless revealed in equilibrium.

Figure 5 shows the timing of shocks and indicates that within each period lenders make decision at two points in time (early and late). First, early in the period after the aggregate productivity shock is realized, lenders that have not defaulted previously choose $\chi_{i,t}$ to maximize

$$\chi_{i,t} E_t^e V^{ND} (\bar{\mathbf{s}}_{i,t} |_{\chi_{i,t}=1}; \bar{\mathbf{S}}_t) + (1 - \chi_{i,t}) E_t^e V^D (\bar{\mathbf{s}}_{i,t} |_{\chi_{i,t}=0}; \bar{\mathbf{S}}_t),$$

where E_t^e denotes expectations early in the period before the realization of the investment shock, $\bar{\mathbf{s}}_{i,t} = \{x_{i,t-1}, \{a_{i,j,t-1}^P\}, \{a_{i,j,t-1}^S\}, h_{i,t-1}^O, l_{i,t}^O, r_{i,t}^{EG}, r_{i,t}^{IG}, \sigma_{i,t-1}, \kappa_{i,t}, \chi_{i,t}\} \forall j$ is the vector of individual state variables and $\bar{\mathbf{S}}_t = \{K_t, \omega_t, A_t, \Sigma_t\}$ is the vector of aggregate state variables.¹⁹ V^{ND} and V^D are the value functions of lenders that have never defaulted and lenders that have defaulted previously, respectively. Those value functions are maximized late in the period. After the realization of the investment shock, lenders choose $c_{i,t}, x_{i,t}, \{a_{i,j,t}^P\} \forall j \in \mathcal{I}_t, \{a_{i,j,t}^S\} \forall j \in \mathcal{I}_{t-1}, h_{i,t}^O, l_{i,t}^O, r_{i,t+1}^{EG}$ and $r_{i,t+1}^{IG}$ to maximize:

$$\begin{aligned} V^{ND} (\bar{\mathbf{s}}_{i,t}; \bar{\mathbf{S}}_t) &= \max[\log(c_{i,t}) + \beta E_t[\chi_{i,t+1} V^{ND} (\bar{\mathbf{s}}_{i,t+1} |_{\chi_{i,t+1}=1}; \bar{\mathbf{S}}_{t+1}) \\ &\quad + (1 - \chi_{i,t+1}) V^D (\bar{\mathbf{s}}_{i,t+1} |_{\chi_{i,t+1}=0}; \bar{\mathbf{S}}_{t+1})]] \\ V^D (\bar{\mathbf{s}}_{i,t}; \bar{\mathbf{S}}_t) &= \max[\log(c_{i,t}) + \beta E_t V^D (\bar{\mathbf{s}}_{i,t+1}; \bar{\mathbf{S}}_{t+1})], \end{aligned}$$

subject to the SGC $s_{i,t} \leq \theta$ and budget constraints

$$c_{i,t} + x_{i,t} + \sum_{\substack{j \in \mathcal{I}_t \\ j \neq i}} a_{i,j,t}^P q_{j,t}^P + \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t}^S q_{j,t}^S + h_{i,t}^O q_t^h + l_{i,t}^O q_t^l = w_{i,t} + s_{i,t} x_{i,t} q_{i,t}^P \quad \forall i, \forall t. \quad (27)$$

A lender's wealth at the beginning of the period t is determined by:

$$\begin{aligned} w_{i,t} &= \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t-1}^P (\hat{r}_{j,t} + \lambda q_{j,t}^S) + \left(h_{i,t-1}^O + \sum_{j \in \mathcal{I}_{t-2} \cap \mathcal{H}_{t-2}} a_{i,j,t-1}^S \right) (r_t^h + \lambda q_t^h) \\ &\quad + \left(l_{i,t-1}^O + \sum_{j \in \mathcal{I}_{t-2} \cap \mathcal{L}_{t-2}} a_{i,j,t-1}^S \right) (r_t^l + \lambda q_t^l) - (g_{i,t}^T - y_{i,t}) s_{i,t-1} x_{i,t-1}. \end{aligned} \quad (28)$$

Finally, lenders who lost reputation due to a default on implicit recourse in period \bar{t} suffer a punishment in the form of an additional constraint: $s_{i,t} = 0 \forall t \geq \bar{t}$.

Following the identification of security types, I can derive their aggregate laws of motion. First, all non-depreciated securities issued in period $t - 1$ become in period t securities “issued

¹⁹ $\kappa_{i,t}$ is the individual realization of the investment shock and $\sigma_{i,t}$ is the variable keeping track of a lender's i default history, whose law of motion is $\sigma_{i,t} = \sigma_{i,t-1} + (1 - \chi_{i,t})$. If the lender has never defaulted on the implicit recourse, then $\sigma_{i,t} = 0$. Σ_t is the distribution of wealth across lenders.

in previous period”:

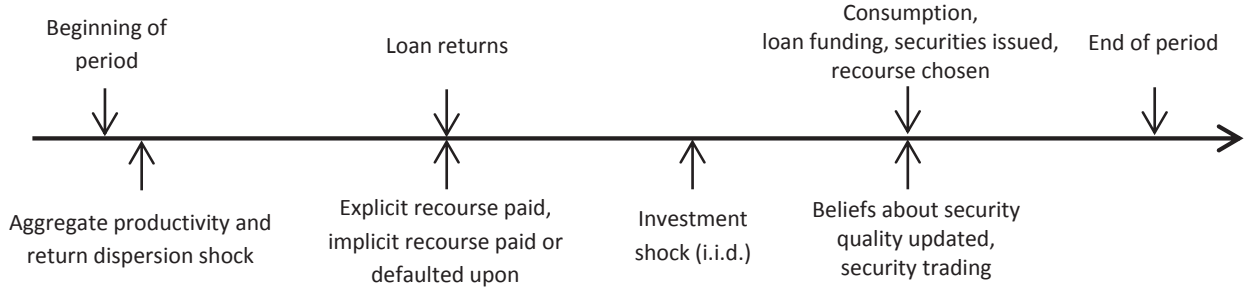
$$\sum_i \sum_{j \in \mathcal{I}_{t-1}} a_{i,j,t}^S = \sum_i \sum_{j \in \mathcal{I}_{t-1}} \lambda a_{i,j,t-1}^P$$

Second, securities with status “issued in previous period” in period $t - 1$ will be added in period t to the stock of non-depreciated high- or low-quality “old” securities of known quality:

$$\begin{aligned} H_{t+1}^O &= \sum_i h_{i,t+1}^O = \sum_i \sum_{j \in \mathcal{H}_{t-2}} \lambda a_{i,j,t-1}^S + \sum_i \lambda h_{i,t-1}^O, \\ L_{t+1}^O &= \sum_i l_{i,t+1}^O = \sum_i \sum_{j \in \mathcal{L}_{t-2}} \lambda a_{i,j,t-1}^S + \sum_i \lambda l_{i,t-1}^O. \end{aligned}$$

Appendix B states the equilibrium definition and derives the optimality conditions.

Figure 5. Timing of shocks and choice of a lender’s controls within each period



4.1.3 Goods and security markets’ clearing

The goods market clearing condition requires output Y_t to be consumed or invested ($Y_t = C_t + X_t$) and determines the average security price in the economy. Relative prices for securities of different vintages and issued by different lenders are determined by indifference conditions of security buyers that equalize the expected returns from traded securities (see their first-order conditions (FOC) in Appendix B).

Recall that all projects depreciate over time, so the law of motion for capital (stock of projects) is $K_{t+1} = \lambda K_t + X_t$.²⁰

4.2 Equilibrium characterization in the deterministic steady state

Under constant aggregate productivity, the full model can be solved analytically and propositions in Section 3 can be re-derived for the full model. In this section, I reiterate the main

²⁰ Similar laws hold for both types of capital (high- and low-quality): $H_{t+1} = \lambda H_t + X_t^h$, $L_{t+1} = \lambda L_t + X_t^l$. As in Kiyotaki and Moore (2012), I assume that the subjective discount factor exceeds the share of capital left after depreciation: $\beta > \lambda$.

results regarding the role of frictions. Proofs are in the Appendix C.

When the SGC constraint is not binding, only high-quality loans are funded; the price of high-quality securities equals the lending costs $q^h = 1$; and the amount and allocation of lending, output and aggregate consumption is the first-best. The current period gross return per unit of lending plus the next-period value of non-amortized securities is equal to the time preference rate $r^h + \lambda = \frac{1}{\beta}$.

The SGC constraint becomes binding when the fraction of investment that has to remain on balance sheets of lenders with high-quality loans, $(1 - \theta)$, exceeds their share of resources $\pi\mu$.

$$(1 - \lambda)(1 - \theta) > \pi\mu, \quad (29)$$

where $(1 - \lambda)$ is the steady state investment to capital ratio. Condition 29 is a more general expression for the condition (15) in Proposition 2.²¹

The asymmetric information friction only has an effect on the equilibrium if the SGC is binding. When condition (29) is satisfied, the equilibrium is separating when loan return dispersions are large enough to satisfy:

$$\frac{r^h}{r^l} > \frac{(1 - \theta)q^h}{1 - \theta q^h} = \frac{(1 - \theta)(1 - \pi\mu)(1 - \lambda)}{\pi\mu(\theta + \lambda(1 - \theta))} \quad (30)$$

in the case where neither explicit nor implicit recourse is available. When only the explicit recourse is available, the necessary condition for the existence of the separating equilibrium is

$$\frac{r^h}{r^l} > \frac{(1 + \tau)q(1 - \lambda\theta\zeta)}{(1 + \tau)q(1 - \lambda\theta\zeta) - \tau(1 - \theta q)(q - 1)}, \quad (31)$$

where ζ is defined in (C.12) in Appendix C. Finally, when only the implicit recourse is available the equilibrium is separating when

$$\frac{r^h}{r^l} > \frac{(1 - \theta P)q^h}{1 - \theta P q^h} = \frac{(1 - \theta P)(1 - \pi\mu)(1 - \lambda)}{P\pi\mu(\theta + \lambda(1 - \theta))}, \quad (32)$$

where $P > 1$ is the price premium for the implicit recourse. Conditions (30), (31) and (32) are generalized versions of conditions (18), (21) and (24) in the simple model, respectively. To see that, substitute $\lambda = 0$ and q from (14).

As in the simple model, comparison of the separating condition without recourse (30) with separating conditions with explicit (31) and implicit recourse (32) shows that the latter

²¹Intuitively a smaller depreciation rate $1 - \lambda$ makes the SGC less likely to be binding, because more securities issued in preceding periods remain on balance sheets, which reduces demand for newly issued securities.

are satisfied on a larger parameter subspace. This implies that the provision of recourse improves the allocation of resources. But the RHS of all conditions (30), (31) and (32) exceeds one. Therefore, similar to the simple model version, despite the provision of explicit or implicit recourse, pooling equilibria exist for the small loan return dispersions. Recourse does not eliminate all inefficiencies, which are due to the existence of the binding SGC and asymmetric information friction.

Conditions for the existence of a separating equilibrium requires the loan return dispersion to be sufficiently high. Since the full model features aggregate productivity shocks and a countercyclical return dispersion, asymmetric information varies over the cycle. The following section explores the dynamic implications of this variation.

5 Dynamics

In this section, I show the solution of the full model with aggregate shocks. First, I find that financial frictions and asymmetric information lower output and increase its volatility. Second, I find that introducing signaling increases output, lowers its volatility and makes output growth significantly negatively skewed, i.e., decreases in output when entering recessions are larger than output increases when entering expansions.

Calibration of parameters: The model is calibrated at an annual frequency. The aggregate productivity follows a two-state Markov chain $A_t \in (A^H, A^L)^{22}$ with a transition matrix $\mathcal{P} = [p, 1 - p; 1 - p, p]$. The persistence parameter for the productivity process is $p = 0.9$.²³ The ratio of aggregate productivities $A^H/A^L = 1.0277$ is chosen to match the annual standard deviation of GDP in the USA, which is 2.09% over 1953-2015. The ratio of loan returns (project productivities) in booms $A^l(A^H)/A^h(A^H) = 0.941$ is chosen to match the skewness of output growth in the USA, which is -1.56 over the last three decades (1986-2015), during which market-based financial intermediation including securitization became more widespread. An analogue ratio of loan returns (project productivities) in recession $A^l(A^L)/A^h(A^L) = 0.745$ is set to reflect the delinquency rate of subprime mortgages after 12 months for loans issued in 2007, just prior to the financial crisis (25.5%). Share of high-quality lending opportunities μ is set to 0.82 in order to match an increase of delinquencies on single-family residential mortgages from an average of 1.89% in the period between the recessions of 2001 and 2008-09 to 6.6% in 2008Q4 (one year after the onset of the 2008-09

²²I refer to periods with high (low) productivity as booms (recessions). Note that capital superscripts H, L refer to the aggregate state of the economy and not to the type of investment opportunity.

²³This corresponds to an autocorrelation of quarterly TFP shocks of 0.95.

recession). The annual asset persistence $\lambda = 0.78$ is chosen to replicate the weighted average life (WAL) for RMBS of 54.5 months (Centorelli and Peristiani, 2012). I use some parameterization from Del Negro et al. (2017), which is also referred to for calibration by Kiyotaki and Moore (2012): $\alpha = 0.34$, $\beta = 0.96$ (annualized), $\theta = 0.792$ and $\pi = 0.04$ (annualized).²⁴ Finally, for simplicity I assume that additional costs of explicit recourse are large enough, $\tau = 0.35$, so that only implicit recourse is provided in equilibrium. Appendix E relaxes this assumption and shows that lower regulatory costs, τ , increase the explicit recourse provision, which in turn reduces the output volatility and negative skewness of output growth.

Solution method: The model with aggregate shocks is solved using a global numerical approximation method.²⁵ In particular, I find price and value functions by iterating them on a grid of state variables until convergence (see Appendix D).

Results: Table 2 compares the standard deviation of output and skewness of output growth in different model versions. We can see that, compared to the first-best case, the introduction of frictions increases output volatility and makes skewness of output growth slightly negative. Allowing signaling by recourse in the constrained case reduces output volatility compared to the constrained case without signaling, but moves skewness of output growth much further into the negative territory.

To understand the mechanism behind these effects, I plot selected policy functions and impulse responses in Figures 6-8. Figure 6 shows the equilibrium share of lenders with low-quality (LQ) lending opportunity that issue loans as a function of state variables: $\phi_t(A_t, \omega_{t-1}, K_{t-1})$.²⁶ We can see that in the boom ($A_t = A^H$) irrespective of the signaling, the equilibrium is pure pooling, i.e., all lenders with low-quality opportunities lend ($\phi_t = 1$). Lending is so profitable that even use of recourse as a signaling tool does not separate any lenders with low-quality loans. In a recession, the share of lenders with low-quality lending opportunities that decide to lend drops in both cases, but by much more in the case with signaling. In this calibration, signaling leads to a complete separation in recessions ($\phi_t = 0$).

²⁴Del Negro et al. (2017) acknowledge the value for π is lower than in the literature on lumpy investment, but justifies it by “using financial data rather than technological data on lumpy investment” and considering firms as those “funneling resources from saving to investing agents and facing the financing constraint” (Del Negro et al., 2017, p. 840-1). My application is also closer to this interpretation. Moreover, relatively lower (tighter) π in my model compared to, for instance, Kiyotaki and Moore (2012) compensates for a more relaxed SGC ($\theta = 0.19$ in Kiyotaki and Moore (2012) vs. 0.792 in this paper) and for the absence of the resaleability constraint.

²⁵See, e.g., Judd (1998) for the description of global numerical methods and their distinction from local numerical methods.

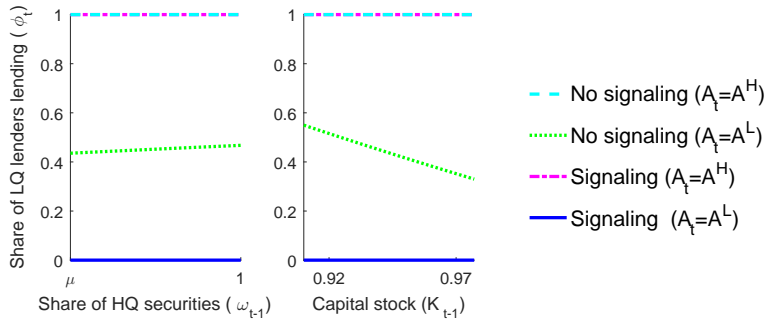
²⁶In a separating equilibrium $\phi_t = 0$, in a pure pooling equilibrium, where all lenders with low-quality opportunities lend $\phi_t = 1$, and in a mixing pooling equilibrium, where lenders with low-quality lending opportunities are indifferent about lending $\phi_t \in (0, 1)$.

Table 2. Output statistics^a

	Standard deviation	Skewness
Data	2.09	-1.56
First-best case	1.68	0.12
Constrained case without signaling	3.19	-0.38
Constrained case with signaling	2.09	-1.56

^a Statistics for real annual GDP per capita: Standard deviation computed for percentage deviations from Hodrick-Prescott trend (1952-2015). Skewness is of the first-differenced log of GDP per capita (1986-2015). Model statistics (20,000 simulated observations): Standard deviation computed for percentage output deviation from mean and skewness is of the first-differenced output.

Figure 6. In recessions, signaling reduces the share of LQ lenders issuing loans (ϕ_t)

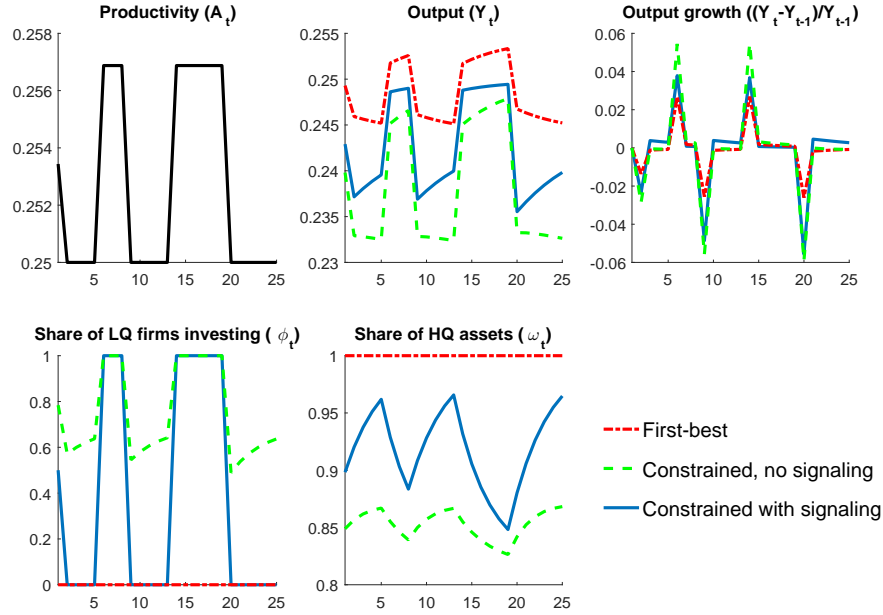


Note: Left panel shows ϕ_t as a function of ω_{t-1} while K_{t-1} is fixed at 0.96. Right panel shows ϕ_t as a function of K_{t-1} , while ω_{t-1} is fixed at 0.91. Both panels show ϕ_t functions separately for A^H and A^L .

Figure 7 shows how the variation in ϕ_t over the cycle translates to output. It compares the response of selected variables to a series of exogenous productivity shocks. All variables start from their respective stochastic steady states²⁷ and are expressed in levels rather than deviations from steady states. We can see that output is lower and more volatile in the constrained cases than in the first-best case. Due to asymmetric information and the binding SGC, the allocation of resources for lending is inefficient. Indeed, as can be seen on the lower panels of Figure 7, many low-quality loans are funded (ϕ_t is positive, especially in a boom), which lowers the balance of outstanding high-quality (HQ) securities in the economy (ω_t). Since the return on low-quality loans is more volatile over the cycle, volatility of output increases in the constrained cases.

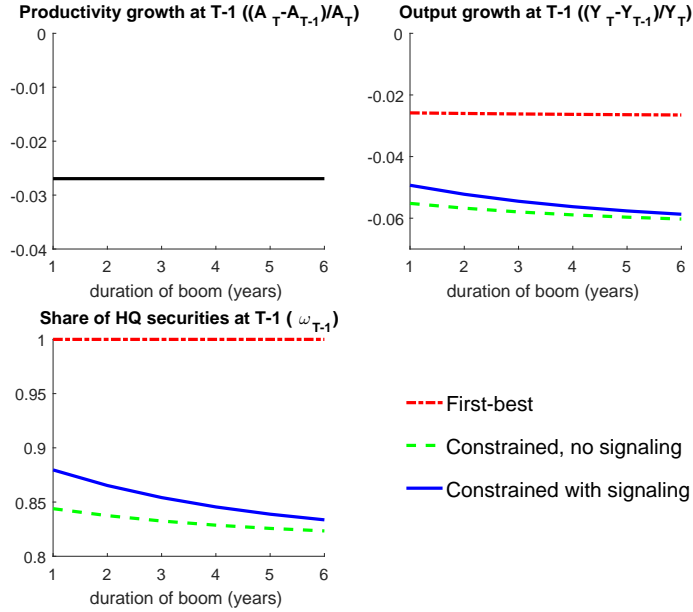
²⁷Productivity in a steady state is kept at the zero-probability mean of the ergodic distribution across (A^H, A^L) with expectations that in the next period each state is equally likely. The impulse responses of endogenous variables start from a steady state to which they converge after many periods of this average productivity.

Figure 7. Impulse responses to productivity shocks



Note: All variables are expressed in levels and start in their respective stochastic steady states.

Figure 8. The longer the boom stage, the deeper the subsequent recession



Note: Recession starts in period T . Figure shows that while the drop of productivity in period T is independent of the duration of a preceding boom, output drop is sensitive in constrained cases, especially when signaling is present, because low-quality securities accumulate on balance sheets during the boom.

Figure 7 shows us also the effect of signaling. We already know from Figure 6 that ϕ varies more over the cycle in the presence of signaling. This implies that the share of high-quality securities on lender balance sheets (ω_t) is also more volatile with signaling, which causes a

larger asymmetry in output growth (negative skewness of output growth). Indeed, signaling cleans up the balance sheets of lenders from low-quality securities during recessions, so the output already recovers slowly in the low-productivity state. When the economy moves to a high-productivity state, the output increase is lower than in the absence of signaling, where a larger quantity of low-quality securities starts to perform significantly better. Analogously, in a boom low-quality loans are financed and the composition of lenders' balance sheets worsens relatively faster in the case with signaling (ω_t drops relatively faster). Therefore, at the end of the boom, there is a larger fraction of low-quality securities that amplify the output drop when the economy switches to a recession.

Figure 8 shows that in the constrained cases, the longer the boom period preceding the recession, the smaller the fraction of high-quality securities on lender balance sheets when entering the recession (ω_{T-1}), and the more negative the change in output at the entry to the recession ($(Y_T - Y_{T-1})/Y_T$). This feature is significant mainly in the presence of signaling.

6 Conclusion

I investigate the efficiency of financial intermediation through securitization in a DSGE model. In particular, I study how design of derivative securities using explicit and implicit recourse affects the information asymmetry over the business cycle and what its macroeconomic consequences are.

Empirical analysis suggests that the explicit recourse (credit enhancement) may in some countries signal the quality of securities. However, I also find that the signaling relationship disappears for the subset of securitization deals issued in the boom stage of the business cycle. In the theoretical sections I endogenously replicate this result both for costly explicit recourse and for implicit recourse, for which detailed data is not available. Indeed signaling reduces the problem of asymmetric information in recessions. However, the higher costs of explicit recourse and the credibility limits of implicit recourse make this signaling inefficient in the boom stages of business cycles, characterized by high productivity and low return dispersion. Due to this mechanism, low-quality loans are financed in boom times and accumulate on lender balance sheets, which then amplify a subsequent downturn of the economy. This variation in asymmetric information over the business cycle ultimately results in a growth asymmetry in business cycles observed in the data.

The mechanism presented in this paper contributes to the understanding of the recent financial crisis, since it describes the experience of securitization markets prior to and during the crisis. In the preceding period, many inefficient investments of unknown quality were undertaken. While this was not problematic as long as the economy was performing well,

the large amount of low-quality loans in the economy ultimately contributed to the depth of the financial crisis. The results are relevant for the regulation of securitization since they suggest that self-regulation by risk-retention is inefficient in the boom.

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References

- Acemoglu, D., Scott, A., 1997. Asymmetric business cycles: Theory and time-series evidence. *Journal of Monetary Economics* 40, 501–533.
- Acharya, V. V., Schnabl, P., 2010. Do global banks spread global imbalances? asset-backed commercial paper during the financial crisis of 2007-09. *IMF Economic Review* 58 (1), 37–73.
- Adrian, T., Shin, H., 2009. Money, liquidity, and monetary policy. *American Economic Review: Papers and Proceedings* 99 (2), 600–605.
- AFME, 2013. The economic benefits of high quality securitizations to the EU economy. Association for Financial Markets in Europe.
- Almazan, A., Martín-Oliver, A., Saurina, J., 2015. Securitization and banks' capital structure. *The Review of Corporate Finance Studies* 4 (2), 206–238.
- Bigio, S., 2013. Endogenous liquidity and the business cycle. *American Economic Review* 105 (6), 1883–1927.
- Bloom, N., 2009. The impact of uncertainty shocks. *Econometrica* 77 (3), 623–685.

- Bloom, N., Floetotto, M., Jaimovich, N., Sapora-Eksten, I., Terry, S., 2012. Really uncertain business cycles. NBER Working Papers (18245).
- Brunnermeier, M., 2009. Deciphering the liquidity and credit crunch 2007-2008. *Journal of Economic Perspectives* 23 (1), 77–100.
- Centorelli, N., Peristiani, S., 2012. The role of banks in asset securitization. *FRBNY Economic Policy Review* 18 (2), 47–63.
- Chari, V. V., Shourideh, A., Zetlin-Jones, A., 2014. Reputation and persistence of adverse selection in secondary loan markets. *American Economic Review* 104, 4027–70.
- Cho, I.-K., Krepes, D. M., 1987. Signaling games and stable equilibria. *The Quarterly Journal of Economics* 102 (2), 179–222.
- Del Negro, M., Eggertsson, G., Ferrero, A., Kiyotaki, N., March 2017. The great escape? a quantitative evaluation of the fed’s liquidity facilities. *American Economic Review* 107 (3), 824–57.
- Dell’Ariccia, G., Marquez, R., 2006. Lending booms and lending standards. *The Journal of Finance* 61 (5), 2511–2546.
- DeMarzo, P., 2005. The pooling and tranching of securities: A model of informed intermediation. *The Review of Financial Studies* 18 (1), 1–35.
- DeMarzo, P., Duffie, D., 1999. A liquidity-based model of security design. *Econometrica* 67 (1), 65–99.
- Gertler, M., Kiyotaki, N., 2010. Financial intermediation and credit policy in business cycle analysis, 1st Edition. Vol. 3. In: Friedman, B. and Woodford, M. (Eds.), *Handbook of Monetary Economics*. Elsevier, Ch. 11, pp. 547–599.
- Gorton, G., Pennacchi, G., 1995. Banks and loan sales: Marketing nonmarketable assets. *Journal of Monetary Economics* 35 (3), 389–411.
- Gorton, G., Souleles, N., 2006. Special purpose vehicles and securitization. In: Carey, M. and Stulz, R. (Eds.), *The risks of financial institutions*. University of Chicago Press, Chicago, pp. 549–602.
- Guvenen, F., Ozkan, S., Song, J., 2014. The nature of countercyclical income risk. *Journal of Political Economy* 122 (3), 621–660.
- Hansen, G. D., Prescott, E. C., 2005. Capacity constraints, asymmetries, and the business cycle. *Review of Economic Dynamics* 8, 850–865.
- Higgins, E., Mason, J., 2004. What is the value of recourse to asset-backed securities? A clinical study of credit card banks. *Journal of Banking and Finance* 28 (4), 875–899.
- Jovanovic, B., 2006. Asymmetric cycles. *The Review of Economic Studies* 73 (1), 145–162.

- Judd, K. L., 1998. Numerical methods in economics. MIT press.
- Keys, B. J., Mukherjee, T., Seru, A., Vig, V., 2010. Did securitization lead to lax screening? Evidence from subprime loans. *The Quarterly Journal of Economics* 125 (1), 307–362.
- Kiyotaki, N., Moore, J., 2012. Liquidity, business cycles and monetary policy. NBER Working Papers (17934).
- Kocherlakota, N. R., 2000. Creating business cycles through credit constraints. *Federal Reserve Bank of Minneapolis Quarterly Review* 24 (4), 2–10.
- Kuncl, M., 2016. Fragility of resale markets for securitized assets and policy of asset purchases. Bank of Canada Staff Working Paper (46).
- Leland, H. E., Pyle, D. H., 1977. Informational asymmetries, financial structure, and financial intermediation. *The Journal of Finance* 32 (2), 371–387.
- Lown, C., Morgan, D., 2006. The credit cycle and the business cycle: New findings using the loan officer opinion surveys. *Journal of Money, Credit and Banking* 38 (6), 1575–1597.
- Maddaloni, A., Peydró, J.-L., 2011. Bank risk-taking, securitization, supervision, and low interest rates: Evidence from the Euro-area and the US lending standards. *The Review of Financial Studies* 24 (6), 2121–2165.
- Mandel, B. H., Morgan, D., Wei, C., 2012. The role of bank credit enhancements in securitization. *FRBNY Economic Policy Review* 18 (2), 35–46.
- Mian, A., Sufi, A., 2009. The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis. *The Quarterly Journal of Economics* 124 (4), 1449–1496.
- Myers, S. C., Majluf, N. S., 1984. Informational asymmetries, financial structure, and financial intermediation. *Journal of Financial Economics* 13 (2), 187–221.
- Nakajima, M., Ríos-Rull, J.-V., 2014. Credit, bankruptcy, and aggregate fluctuations. NBER Working Paper 20617.
- Nieuwerburgh, S. V., Veldkamp, L., 2006. Learning asymmetries in real business cycles. *Journal of Monetary Economics* 53 (4), 753 – 772.
- Ordoñez, G., 2014. Confidence banking and strategic default. Mimeo. University of Pennsylvania and NBER.
- Ruckes, M., 2004. Bank competition and credit standards. *The Review of Financial Studies* 17 (4), 1073–1102.